MRI

Effect of Controlled Burning on Soil Erodibility by Wind

Final Test Report

For
Radian International

JUL 2001
RECEIVED
RECORDS CENTER

MRI Project No. 110056

May 16, 2001

DOCUMENT CLASSIFICATION
REVIEW WAIVER PER
CLASSIFICATION OFFICE

ADMIN RECORD

SW-A-004357

Midwest
Research
Institute

425 Volker Boulevard
Kansas City, Missouri
64110-2299
(816) 753-7600

solutions through science and technology

1/54

MRI

Effect of Controlled Burning on Soil Erodibility by Wind

Final Test Report

For
Radian International
P.O. Box 201088
Austin, Texas 78720-1088

MRI Project No. 110056.1.002

May 16, 2001

2

Midwest Research Institute • 425 Volker Boulevard • Kansas City, Missouri 64110-2299

Preface

This report was prepared by Midwest Research Institute (MRI) for Radian International under Purchase Order No. 803991. In this report, MRI presents the methodology and results of the wind erodibility testing of burned and unburned grassland at the Rocky Flats Environmental Technology Site, located northwest of Denver, Colorado.

The work was conducted in MRI's Applied Engineering Division. Dr. Chatten Cowherd, who served as the project leader for MRI, coordinated the preparation of this report. Other MRI technical staff who contributed to the program were Mary Ann Grelinger (data acquisition) and Courtney Kies (data reduction).

MIDWEST RESEARCH INSTITUTE

Chatten Cowherd

Chatten Cowherd, Ph.D.
Program Manager

Approved:

Paul C. Constant

Paul C. Constant, P.E.
Acting Director
Applied Engineering Division

May 16, 2001

Contents

Figures

Tables

Section 1. Introduction

The purpose of this study was to determine the impact of a prescribed vegetative burn on the potential for wind-generated particulate emissions from soils and vegetation at the Rocky Flats Environmental Technology Site northwest of Denver. A controlled 50-acre test burn took place on April 6, 2000. Wind tunnel tests were performed by Midwest Research Institute (MRI) on representative portions of the test-burn area (Figure 1) and also on an adjacent unburned grassy area within the Rocky Flats site.

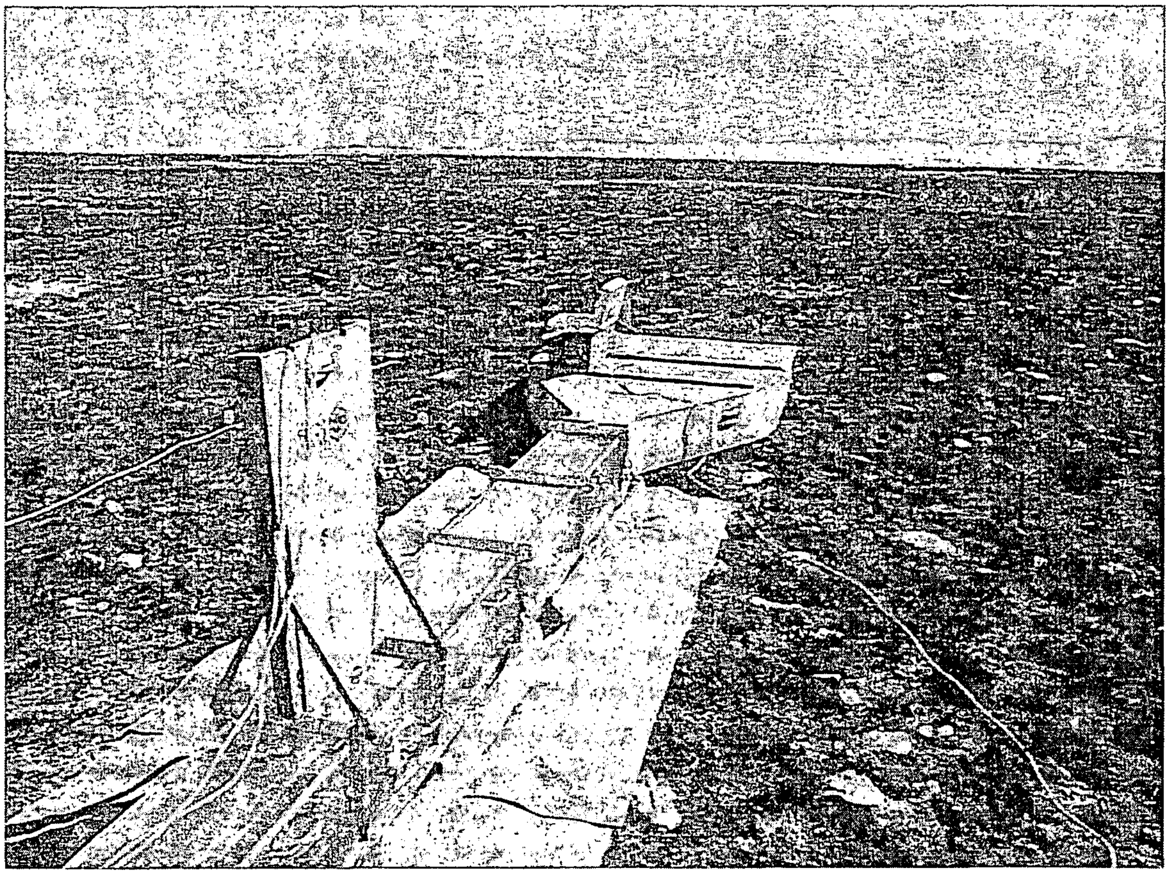


Figure 1. MRI Wind Tunnel on Prescribed Burn Area at Rocky Flats, April 2000

The testing was initiated the day after the controlled burn of the grassland. Subsequent tests over a period of three months (April to June 2000) were conducted to evaluate the length of time it takes for new vegetation to restore soil protection against high wind events. Test objectives were also to determine (a) whether a clearly evident threshold velocity exists for the onset of wind erosion, (b) how dust emissions increase from one wind speed plateau to the next, and (c) how the emissions decay in time at a given wind speed.

The primary test device used in the evaluation was MRI's portable reference wind tunnel with a time-integrating air sampler for collection of PM-10 (particles less than or equal to 10 μm in aerodynamic diameter). Two TSI DustTRAK monitors were connected to the wind tunnel to provide real-time concentrations of PM-10 and PM-2.5 in the tunnel effluent. Carbon analysis of filters used during the field testing was done to separate the soil component from the ash component of the PM-10 collected. In addition to field testing, laboratory dustiness tests were run on bulk surface soil samples from burned areas to characterize the soil texture, including the PM-10 and PM-2.5 dustiness, and the natural mitigative effect of soil moisture.

This report describes (a) the types of equipment and the procedures that were used in field testing at Rocky Flats and laboratory testing at MRI and Desert Research Institute, and (b) the results of testing along with an analysis of field and laboratory test results. The report is organized as follows:

- Section 2 describes the equipment and procedures used for field sampling of the controlled burn area and for laboratory tests of surface soil samples and PM-10 filters from the wind tunnel testing.
- Section 3 presents the wind tunnel test results together with an analysis and interpretation of the test results.
- Section 4 presents the laboratory test results together with an analysis and interpretation of the test results.
- Section 5 concludes the report with a summary of the test results and the conclusions that can be drawn from the results.
- Section 6 lists the literature references.

Section 2.
Test Methods

Field tests were performed to observe the effect of wind speed on the particulate emissions generated from unburned and burned grassland areas at Rocky Flats. The impact of the controlled vegetative burn on the soil emission potential was evaluated over a three-month period using MRI's portable reference wind tunnel along with two TSI DustTRAK monitors.

The MRI portable pull-through wind tunnel, as described in the *Air/Superfund National Technical Guidance Study Series, Volume II, Estimates of Baseline Air Emissions at Superfund Sites* (USEPA, 1989), was used in performing the field study of wind-generated emissions from the controlled burn area. This MRI reference wind tunnel (Figure 2) features all of the required design and operating characteristics, including the equipment for extracting isokinetic samples of wind generated particulate matter for measurement of mass emissions and particle size distribution. It is powered by a gasoline engine with direct mechanical linkage to the primary blower, which pulls the airflow through the tunnel.

In operating the wind tunnel, the open-floored test section is placed directly over the surface to be tested. Air is drawn through the tunnel at controlled velocities. The exit air stream from the test section passes through a circular duct fitted with a sampling probe near the downstream end. Air is drawn through the probe by a high-volume sampling train that separates total airborne particulate (TP) emissions into two particle size fractions: particles larger than 10 µm in aerodynamic diameter and particles smaller than 10 µm in aerodynamic diameter (PM-10). Note that TP contains particles as large as several hundred microns in diameter that are released from the test surface under high wind conditions. Interchangeable probe tips are sized to provide for isokinetic sampling, so that large particle sampling biases do not occur.

A high-volume ambient air sampler is operated near the inlet of the wind tunnel to provide for measurement and subtraction of the contribution of the ambient background particulate level. By sampling under light ambient wind conditions, background interferences from upwind erosion sources can be minimized.

The wind tunnel method relies on a straightforward mass balance technique for calculation of emission rate and no assumptions about plume configuration are required. This technique provides for precise study of the wind erosion process on specific test surfaces for a wide range of wind speeds. Previous wind erosion studies using the MRI reference wind tunnel have led to the EPA recommended emission factors presented in *Compilation of Air Pollutant Emission Factors (USEPA, 2000).*

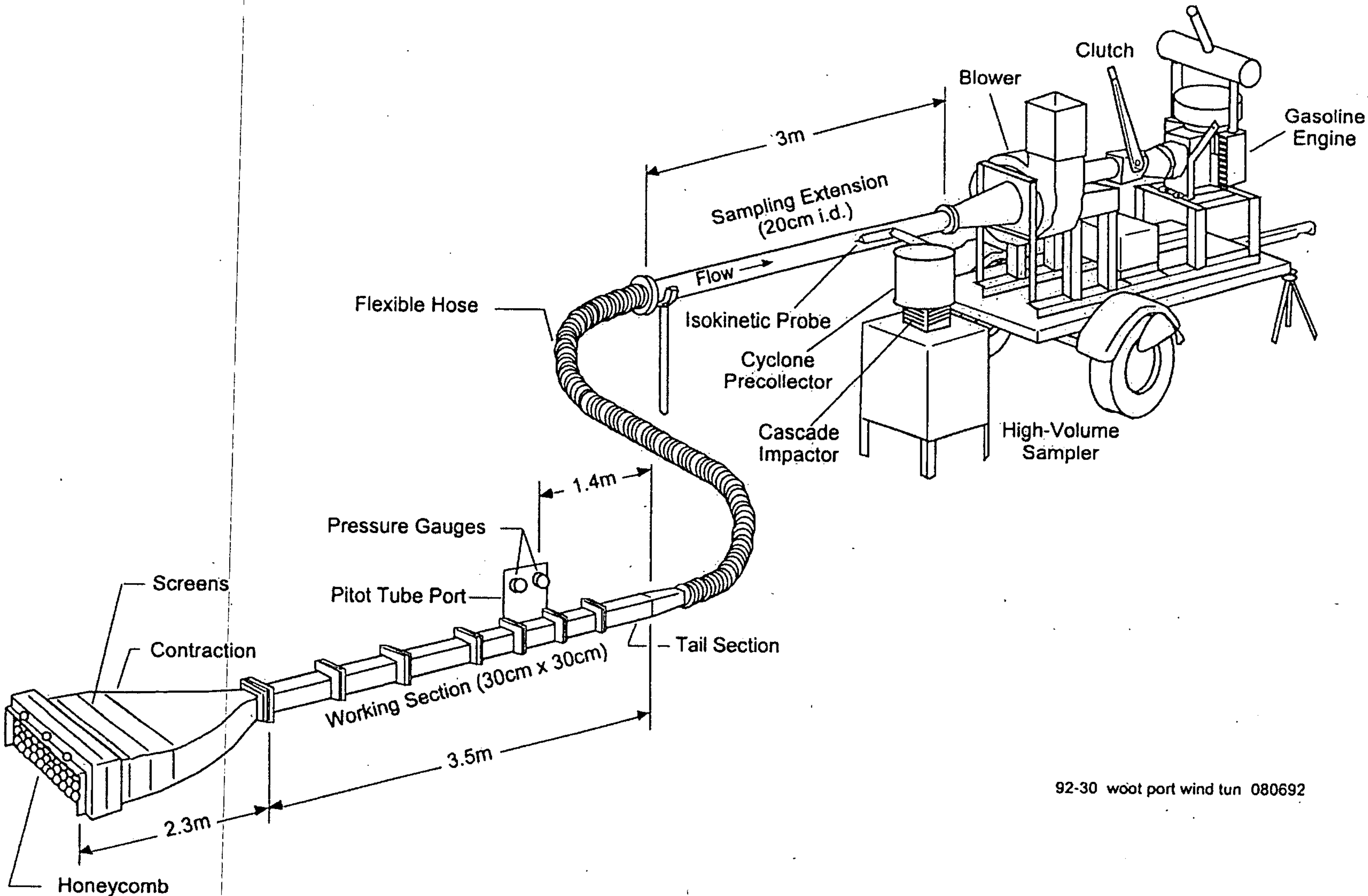


Figure 2. MRI Portable Wind Tunnel

2.1 Wind Tunnel Sampling Equipment

The MRI reference wind tunnel (Figure 2) is identical in design to that developed by Gillette (Gillette, 1978) but is nearly twice as large. It consists of a two-dimensional 5:1 contraction section, an open-floored working section with a 30 cm by 30 cm cross-section, and a roughly conical diffuser. The test area of this tunnel (30 cm by 3.1 m) provides for its use on rougher surfaces. The tunnel centerline airflow is adjustable up to an approximate maximum speed of 19 m/s (40 mph), as measured by a pitot tube at the downstream end of the test section. The equivalent wind speed at a reference height of 10 m above the ground is approximately two to three times the speed at the tunnel centerline.

Although the portable wind tunnel does not generate the larger scales of turbulent motion found in the atmosphere, the turbulent boundary layer formed within the tunnel simulates the smaller scales of atmospheric turbulence. It is the smaller scale turbulence that penetrates the wind flow in direct contact with the erodible surface and contributes to the particle entrainment mechanisms. The MRI reference wind tunnel has been used to develop USEPA AP-42 emission factors for industrial wind erosion (Cowherd, 1988).

The wind speed profiles near the test surface (tunnel floor) and the walls of the tunnel have been shown to follow a logarithmic distribution (Gillette, 1978):

$$u(z) = \frac{u^*}{0.4} \ln \frac{z}{z_0} \tag{1}$$

where: u = wind speed, cm/s
u^* = friction velocity, cm/s
z = height above test surface, cm
z_o = roughness height, cm

The friction velocity, which is a measure of wind shear at the erodible surface, characterizes the capacity of the wind to cause surface particle movement. As indicated from Equation 1, the wind velocity at any fixed height above the surface (but below the centerline of the wind tunnel) is proportional to the friction velocity. The "micro-scale" roughness height of each test surface is determined by extrapolation of the logarithmic wind speed profile near the surface to where $u = 0$.

An emissions sampling module (referred to in Figure 2 as the sampling extension) provides for representative extraction and aerodynamic sizing of particulate emissions generated by wind erosion. The sampling module is located between the tunnel outlet hose and the fan inlet. The particulate sampling train, which is operated at 68 m^3/h (40 acfm), consists of a tapered probe, cyclone precollector, glass fiber backup filter, and high-volume motor. The sampling intake is pointed into the air stream, and the sampling velocity is adjusted to the approaching air speed by fitting the intake with a nozzle of appropriate size.

When operated at 68 m^3/h (40 cfm), the cyclone has a nominal cutpoint of 10 μm aerodynamic diameter, based on laboratory calibration (Baxter et al., 1986). Thus the particulate fraction that penetrates the cyclone constitutes PM-10.

A pitot tube is used to measure the centerline (CL) wind speed in the sampling extension, upstream of the point where the sampling probe is installed. The volumetric flow rate through the wind tunnel is determined from a published relationship (Ower and Pankhurst, 1969) between the centerline (maximum) velocity in a circular duct and the average velocity, as a function of Reynolds' number. Because the ratio of the centerline wind speed in the sampling extension to the centerline wind speed in the working section is nearly independent of flow rate, the ratio can be used to determine isokinetic sampling conditions for any flow rate in the tunnel.

A portable high-volume air sampler with an open-faced glass fiber filter is operated on top of the tunnel inlet section to measure background levels of total suspended particulate matter (TSP). The aerodynamic cutoff diameter of TSP is usually assigned a value of 30 μm aerodynamic diameter. The filter is vertically oriented, parallel to the tunnel inlet face. Approximately half of the mass collected on the filter is assumed to be PM-10. The sampler is operated at 68 m^3/h (40 cfm).

2.2 Wind Tunnel Sampling Procedure

Prior to each test series, the working section of the tunnel is placed directly on the selected test surface. To prevent air infiltration under the sides of the open-floored section, the rubberized skirts, attached to the bottom edges of the tunnel sides, are stretched out on the surface adjacent to the test surface. Rubber inner tubes filled with sand are laid along the skirts to assure a tight seal.

With the tunnel in place, the airflow is gradually increased to the threshold for the onset of wind erosion, as determined by visual observation of migration of coarse particles, and then reduced slightly. At the sub-threshold flow, a wind speed profile is measured and a surface roughness height is determined. In the absence of a clearly evident threshold velocity, the wind speed profile is measured at a tunnel centerline wind speed of approximately 9 m/s (20 mph).

The measured micro-scale roughness height allows for conversion of the tunnel centerline wind speed to the equivalent friction velocity and to the equivalent wind speed at a standard 10-m height, using the logarithmic wind speed profile. If the terrain roughness (rolling hills, vegetation, etc.) is much larger than the microscale roughness of the test plot, a separate area-wide roughness height reflecting the larger terrain features is used to convert the tunnel centerline wind speed to the equivalent wind speed at a standard 10-m height.

For test surfaces that are found to have a well-defined threshold velocity, sampling is initiated just after the tunnel centerline wind speed reaches the first prescribed super-threshold level corresponding to the desired friction velocity or wind speed corrected to a height of 10 m. After the prescribed sampling period, the flow is shut off and the particulate samples (cyclone catch and glass fiber backup filter) are removed.

At the end of each test, the sampling train is disassembled and taken to the field instrument van and the collected samples of dust emissions are carefully placed in protective containers. For transfer of samples to a laboratory setting, high-volume filters are placed in individual protective envelopes or in specially designed carrier cases. Dust is transferred from the cyclone precollector by brushing it into a tared clear, resealable plastic pouch. Alternatively, the cyclone catch can be sieved using a standard 325 sieve (45 μm pore size). The sieved cyclone catch when recombined with the PM-10 mass from the backup filter, represents total suspended particulate matter (TSP), approximately PM-30.

Dust samples from the field tests are returned to an environmentally controlled laboratory for gravimetric analysis. Glass fiber filters are conditioned at constant temperature (23°C ± 1°C) and relative humidity (45% ± 5%) for 24 h prior to weighing (the same conditioning procedure as used before tare weighing). The particulate catch from the cyclone precollector is weighed in the tared pouch.

The raw test data that are recorded include the following:

- Site code and description
- Test date, run number, and type of test
- Sample IDs (filters, cyclone catches, surface soils)
- Start time and sampling duration
- Threshold wind speed at tunnel centerline
- Subthreshold wind speed profile from which microscale roughness height is determined
- Operating wind speeds at tunnel centerline and at centerline of sampling tube
- Sampling module flow rate
- Ambient meteorology (wind speed and direction; temperature; barometric pressure)

2.3 Interpretation of Wind Tunnel Results

Because wind erosion is an avalanching process, it is reasonable to assume that the loss rate from the surface is proportional to the amount of erodible material remaining:

$$\frac{dM}{dt} = - kM \qquad (2)$$

where: M = quantity of erodible material present on the surface at any time, g/m^2
k = proportionality constant, s^{-1}
t = cumulative erosion time, s

Integration of Equation 2 yields:

$$M = M_o e^{-kt} \qquad (3)$$

where M_o = erosion potential, i.e, quantity of erodible material present on the surface before the onset of erosion, g/m^2

The loss of erodible material (g/m^2) from the exposed surface area during a test is calculated as follows:

$$L = \frac{CQt}{A} \qquad (4)$$

where: C = average particulate concentration in tunnel exit stream (after subtraction of background concentration), g/m^3
Q = tunnel flow rate, m^3/s
A = exposed test surface area (0.918 m^2 for the reference wind tunnel)

Alternatively, the erosion potential can be directly calculated from the filter net mass (after correction for background).

Whenever a surface is tested at sequentially increasing wind speeds, the measured losses from the lower speeds are added to the losses at the next higher speed and so on. This reflects the hypothesis that, if the lower speeds had not been tested beforehand, correspondingly greater losses would have occurred at the higher speeds.

Emissions generated by wind erosion are dependent on the frequency of disturbance of the erodible surface because each time that a surface is disturbed, its erosion potential is restored. A disturbance is defined as an action that results in the exposure of fresh surface material. On a soil surface, this would occur whenever soil is either added to or removed from the old surface, or whenever surface material is turned over to a depth exceeding the size of the largest pieces of aggregate present in the soil.

In summary, the calculated test results for each test surface and maximum wind speed include:

- Roughness height (microscale): from extrapolated subthreshold velocity profile
- Friction velocity: from measured centerline wind speed and roughness height, using Equation 1

- Equivalent wind speed at reference 10-m height: from measured centerline wind speed and roughness height, using Equation 1
- Erosion potential (for "limited reservoir" surfaces): equivalent to the cumulative particle mass loss at a particular wind speed

2.4 DustTRAK Monitoring

Continuous monitoring of particulate concentration in the emission sampling module provides for a much greater level of detail in tracking the dynamics of the wind erosion process. In the case of the subject study, two portable DustTRAK Aerosol Monitors (TSI, Inc., St. Paul, Minnesota) continuously sampled air between the cyclone and the backup filter for the purpose of tracking the PM-10 and PM-2.5 concentrations in the tunnel effluent.

The DustTRAK monitor is a portable, battery-operated instrument that gives real-time measurements and has a built-in data logger. It weighs 3.3 lb and uses four C cells. The instrument, as originally configured, samples PM-10, but can be fitted with a Dorr-Oliver nylon cyclone for industrial hygiene sampling (~3.5 μm cutpoint), or impactors for PM-2.5 and PM-1 sampling.

The operating principle of the DustTRAK is based on 90° light scattering. Light scattering (deflected) by local variations in refractive index is caused by the presence of dispersed species whose size is comparable to the wavelength of the incident light. The theoretical detection efficiency based on Mie light scattering theory (developed in 1908) peaks at about 0.2-0.3 μm and gradually decreases for larger particle sizes. A pump draws aerosol into the optics chamber where either solid or liquid particles are detected. A laser diode light source, along with a solid-state photo detector, ensures greater stability and longevity. The specially designed sheath air system is used to isolate the aerosol in the chamber, keeping the optics clean and reducing maintenance. The instrument design gives measurements of particle concentrations from 0.001 to 200 mg/m^3. (Note that the instrument comes precalibrated to indicate mass concentration in mg/m^3 using Arizona road dust as the calibration reference).

The DustTRAK has two basic modes of operation: a survey mode and a logging mode. The survey mode displays real-time aerosol concentration measurements in mg/m^3. The logging mode functions similar to the survey mode with the added feature that the measurements are stored at programmable intervals for trending and reporting using the TrakPro Data Analysis Software.

Once data has been logged by the monitor (30,000 data points can be recorded using 3 logging modes), the DustTRAK software can retrieve the information for a more comprehensive analysis, including maxima, minima, and averages for the entire sampling period or any user-selected interval. The PC software also has a graphing capability that allows the comparison of PM-10 and PM-2.5 concentrations, assuming two monitors are available (one with a PM-2.5 impactor inlet) and simultaneous sampling occurs.

The DustTRAK PM-10 monitor is calibrated against the actual PM-10 mass collected on the back-up filter of the wind tunnel effluent sampling train during a given test run. This calibration entails an integration of the real-time DustTRAK PM-10 concentration profile (versus time) and calculation of the average DustTRAK PM-10 concentration for comparison to the average PM-10 concentration calculated from the net PM-10 mass collected on the back-up filter below the cyclone.

Use of the DustTRAK monitors provides for a more comprehensive analysis of surface erodibility, especially appropriate to the study surfaces that do not have a well defined wind erosion threshold velocity. On the burned vegetative surfaces at Rocky Flats, there are multiple contributors to wind generated particulate emissions: (a) the bulk soil with the usual protection afforded by consolidation, (b) settled surface dust that is trapped by the vegetation, and (c) the vegetation itself. The particle releases from these reservoirs are all driven by different mechanisms, each with a different wind speed dependence.

Thus, the approach taken in this study was (a) to expose each test surface to a well defined time history of increasing wind speeds, and (b) to monitor continuously the PM-10 and PM-2.5 concentrations in the tunnel effluent. Specifically, the wind speed was increased in increments of 2 m/s (5 mph) up to the capacity of the wind tunnel as follows:

Wind Speed at Tunnel CL (mph)	Start Time (min:sec)	Duration (min:sec)
5	0:00	2:00
10	2:00	2:00
15	4:00	2:00
20	6:00	4:00
25	10:00	4:00
30	14:00	4:00
35	18:00	4:00
40	22:00	4:00

Typically, each time the wind speed was increased, a concentration spike was observed. Furthermore, upon each successive increase, the peak value of the spike increased and the rate of decay decreased. For centerline wind speeds at or above 20 mph, the duration of sampling was increased to a minimum of 4 min to allow additional time for the spike to decay. Time integration generates erosion mass increments that when added together yield cumulative erosion potentials for PM-10 and PM-2.5 as a function of wind speed.

An example of the concentration spikes that occur during wind tunnel testing can be seen in Figure 3. The length of time for the emissions to decay to a background level can also be seen.

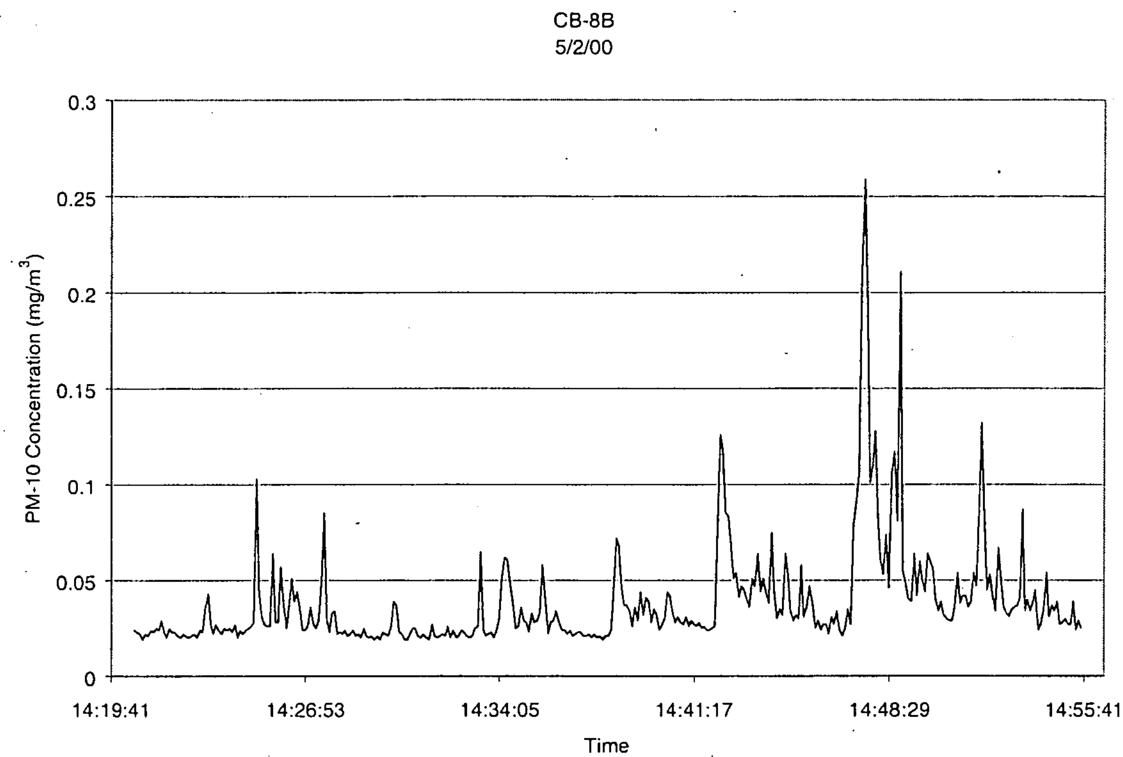


Figure 3. DustTRAK Graph for Run CB-8B

2.5 Surface Soil Sampling

In April and May 2000, six subareas in the controlled burn area were sampled for surface soil. The sample collected from each subarea consisted of a composite of 5 to 8 incremental samples. Each incremental sample was collected from a soil area of about 500 cm^2 between burnt vegetative stubble. The soil samples were collected to a depth of approximately 1 cm to 1.5 cm using a whiskbroom and a dustpan. The six areas from which composite samples were collected were judged to be representative of the wind tunnel test areas.

2.6 Surface Soil Dustiness Testing

The MRI Dustiness Test Chamber (DTC) is a laboratory device used to determine the tendency of finely divided bulk materials (e.g., soils, powders) to release fine particles

(Cowherd et al., 1989). Within the chamber shown in Figure 4, the particles generated from controlled pouring of material are captured on an overhead filter with a sampling rate of 5 L/min. The dustiness test method was originally developed to provide EPA with measures of "dustiness potential" and to quantify the important parameters affecting dustiness, including moisture content and material texture. The DTC has also been used in several studies of contaminated materials to determine the partitioning of contaminants in the fine particle component.

The DTC was adapted to collect PM-10 and PM-2.5 samples for determination of source emission profiles for receptor modeling. For this purpose, size-selective inlets (Figure 4) were fitted to the sampling intake.

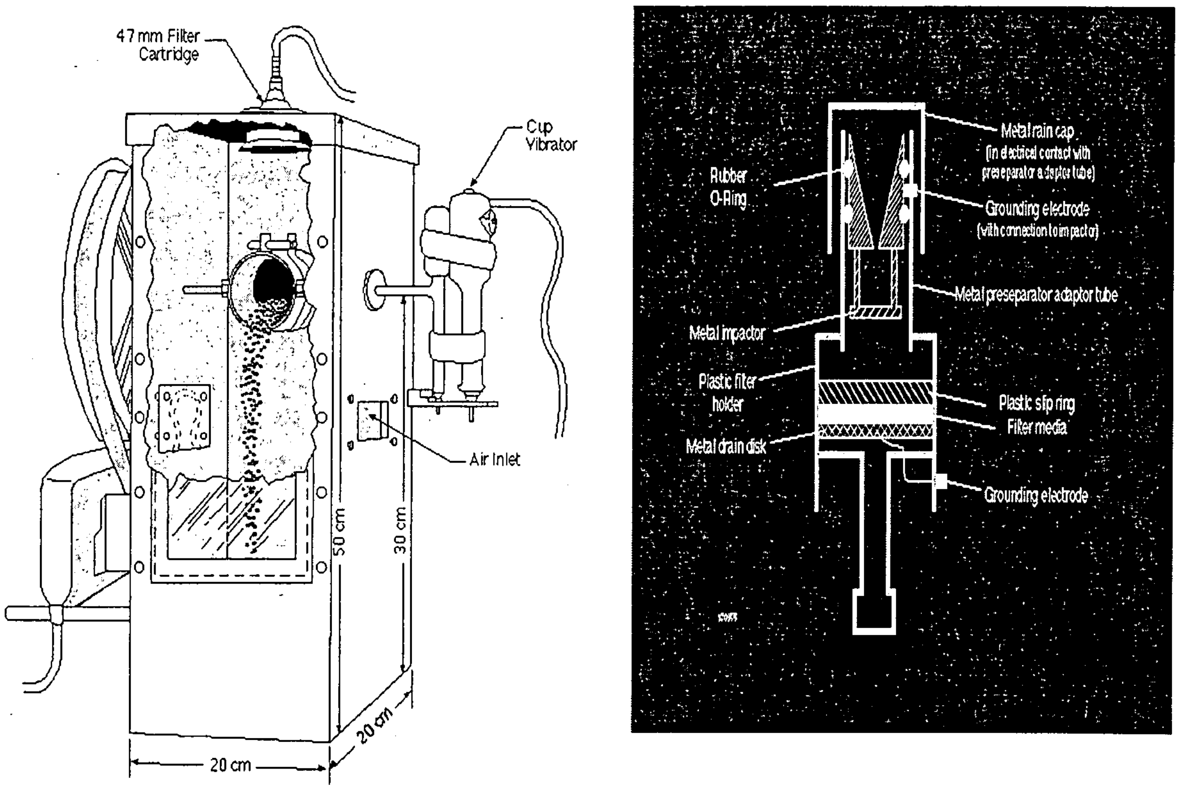


Figure 4. MRI Dustiness Test Chamber and Impactor Assembly (Inverted)

The following steps represent a typical test scenario for sampling particulate matter (PM) suspended during the pouring of material in the DTC.

- Characterize the test material for moisture content (from weight loss upon oven drying).
- Install a clean tare weighed filter in the DTC.
- Record the mass of material to be poured in the chamber.

16

- Pour the test material and evacuate the chamber at 5.0 L/min for 10 min.
- Analyze the filter gravimetrically and record the final filter weight.

The net weight of PM caught on the filter (final filter weight minus tare weight) is divided by the mass of material poured to calculate the mass emission rate in units of mg of dust per kg of material poured. This quantity is defined as the dustiness index of the test material.

2.7 Carbon Analysis of PM-10 Filters

To quantify the ash contribution to the PM-10 mass produced in the wind tunnel testing, elemental carbon (EC) and organic carbon (OC) analysis were performed by Desert Research Institute (DRI) on sections of the 8-in. by 10-in. quartz fiber filters used in the wind tunnel testing and blank field and laboratory filters. The analysis method was Thermal/Optical Reflectance (TOR), as described by Watson and Chow (1994).

The TOR method has been adapted by DRI from Huntzicker et al. (1982) for the quantification of organic and elemental carbon in PM deposited on quartz filters. In the DRI method (Chow et al., 1993), filter mass is volatilized in several temperature ramping steps. Volatilization temperatures range from ambient to 550°C in pure helium atmosphere, then from 550°C and 800°C in a 2 percent oxygen and 98 percent helium mixture. The carbon that evolves at each temperature is converted to methane and quantified with a flame ionization detector.

Associated with the thermal evolution of carbon, the optical reflectance from the deposited mass on the filter is monitored. As the temperature increases in the pure helium atmosphere, the organic material is pyrolized and reflectance typically decreases. When oxygen is added at the higher temperatures, reflectance increases as the light-absorbing "black" elemental carbon is combusted and removed.

Organic carbon is defined as that carbon which is volatilized prior to reattainment of the original reflectance—i.e., carbon that does not absorb light at the wavelength of 632.8 nm. Elemental carbon is defined as the carbon that is volatilized after the original reflectance has been attained—i.e., light-absorbing carbon.

Section 3.
Results of Field Tests

Field tests of the prescribed burn area were performed over one-week periods beginning April 7, May 2, and June 19, 2000. Figure 5 shows the MRI wind tunnel during a prescribed burn area test. During each test the wind tunnel was moved three times over the test area, to collect additional particulate on the back-up filter and improve the detection and precision of the PM-10 erosion potential.

Figure 5. Wind Erosion Testing at Rocky Flats Prescribed Burn Area (April 2000)

The wind tunnel tests were performed at incrementally increasing tunnel centerline wind speeds. The wind speed increments were 2 m/s (5 mph) at the centerline, up to the capacity of the wind tunnel. The "peak" PM-10 and PM-2.5 concentration values (6-sec averages) for each wind speed plateau are observable in the "real-time" concentration histories, recorded by the DustTRAK monitors.

The test site parameters for each of the wind tunnel test runs are provided in Table 1. The surface roughness heights for the test runs were determined by fitting vertical profiles of wind speed in the test section of the wind tunnel to logarithmic functions. An average roughness height was calculated for each test series, for purposes of calculating friction velocities and 10-m equivalent wind speeds.

Table 1. Test Site Parameters

Date	Surface characteristics	Run no.	Start time	Duration (min)	Ambient wind speed (mph)/ direction	Temperature (°F)	Barometric pressure (in. Hg)	Relative humidity (%)	Surface roughness height (cm)
4/7/00	Burned Area (Plot 1)	CB-1A	11:30	44	6 N	51	24.40	43	1.22
		CB-1B	15:32	39	11 NE	51	24.43	35	1.02
		CB-1C	16:40	43	1 SE	59	24.40	25	0.30
4/8/00	Burned Area (Plot 2)	CB-2A	9:09	36	2 SE	49	24.48	44	0.22
		CB-2B	10:28	37	1 ESE	56	24.44	29	1.32
		CB-2C	11:32	35	8 S	59	24.40	27	0.44
4/8/00	Burned Area (Plot 3)	CB-3A	14:06	34	7 E	70	24.30	15	0.60
		CB-3B	15:12	40	2 E	78	24.30	15	0.74
		CB-3C	16:11	37	5 NE/ENE	72	24.30	21	1.32
4/9/00	Unburned, grassy area	CB-4A	9:38	38	7 S	67	24.20	22	1.34
		CB-4B	10:40	33	5.2 S	71	24.18	20	1.88
		CB-4C	11:33	29	5 E	71	24.15	21	1.73
4/10/00	Unburned, grassy area	CB-5A	9:50	35	8 NNE/N	59	24.20	36	1.03
		CB-5B	10:55	32	10 NNE	60	24.20	36	1.62
		CB-5C	12:02	32	14 NE	60	24.20	37	2.64
4/11/00	Unburned, grassy area	CB-6A	8:18	32	3 ENE	43	24.40	70	0.89
		CB-6B	9:14	32	7 SE	48	24.40	61	0.64
		CB-6C	10:06	32	8 S	52	24.40	62	1.22
5/2/00	Burned Area (Plot 7)	CB-7A	9:30	30	6 SSE	62	24.36	48	0.90
		CB-7B	10:19	27	9 SE	64	24.30	40	1.22
		CB-7C	11:07	37	6 SE	67	24.30	39	1.19
5/2/00	Burned Area (Plot 8)	CB-8A	13:23	34	5 ESE	75	24.30	30	1.20
		CB-8B	14:19	35	2 WSW	75	24.25	29	1.20
		CB-8C[a]	15:14	34	5 NNE	79	24.25	27	1.52
5/3/00	Burned Area (Plot 9)	CB-9A	8:56	33	8 E	73	24.30	41	1.73
		CB-9B	9:46	27	NA	74	24.30	40	1.42
		CB-9C	10:59	28	9 NNW	74	24.30	39	1.57
6/21/00	Burned Area (Plot 10)	CB-10A[b]	8:21	43	5 NNE	67	24.40	34	3.00
		CB-10B	11:18	35	5 NE	70	24.60	30	3.00
		CB-10C	13:20	36	4 SE	78	24.90	21	3.00
6/21/00	Burned Area (Plot 11)	CB-11A	14:33	24	4 SE	75	24.80	20	3.32
		CB-11B	15:19	29	3 ENE	83	24.80	16	3.32
		CB-11C	16:13	24	3 SE	77	24.80	14	2.72
6/22/00	Burned Area (Plot 12)	CB-12A	7:56	30	3 ENE	76	24.60	30	3.00
		CB-12B	8:49	32	4 E	76	24.30	29	3.00
		CB-12C	9:45	30	3 E	79	24.60	23	2.72
6/22/00	Unburned, grassy area	CB-13A	13:26	29	5 E	88	24.40	11	3.49
		CB-13B	14:13	29	3 E	88	24.40	11	2.86
		CB-13C	15:02	32	5 ENE	86	24.40	11	3.16
6/23/00	Unburned, grassy area	CB-14A	7:30	33	3 SE/S	68	24.20	38	4.06
		CB-14B	8:27	26	6 S	68	24.20	40	2.12
		CB-14C	9:16	29	5 S	70	24.20	40	3.32
6/23/00	Unburned, grassy area	CB-15A	10:22	31	3 S	79	24.30	10	3.49
		CB-15B	11:16	29	3 S	82	24.30	15	NA
		CB-15C	12:05	29	3 S	92	24.35	8	3.16

[a]Run CB-8C started at 15:14, suspended at 15:18, restarted at 15:23, and ended at 15:53.
[b]Run CB-10A started at 8:21, suspended at 8:30, restarted at 10:21, and ended at 10:55.
NA = No data available.

19

The average PM concentrations from the wind tunnel tests are presented in Table 2. As expected, the average PM-10 concentration in the wind tunnel effluent is much higher for the burned areas (CB-1 to CB-3, CB-7 to CB-12) than for the unburned areas (CB-4 to CB-6, CB-13 to CB-15). Even though high ambient winds were encountered between the time of the prescribed burn (April 6) and the beginning of the first test series (April 7), the average PM-10 erosion potential was found to range from 6.3 to 8.7 times the average PM-10 erosion potential for unburned grassland adjacent to the burned area.

The PM-10 concentrations observed for the June wind tunnel tests of the burned area (CB-10, 11, 12) are slightly higher than the concentrations for the May tests due to the soil moisture level. Soil moisture readings taken in the field during the May test series indicated a damp surface while the April and June readings indicated the soil to be dry. Also, the June wind tunnel tests of the unburned grassland show low additional PM-10 emissions, consistent with results from the April tests of unburned grassland.

It should also be noted that the actual average PM-10 concentration calculated from the tunnel effluent sampler was several times higher than the average PM-10 concentration indicated by the DustTRAK. This reflects the fact that while the coarse mode of the PM-10 (particles larger than 2.5 μm) constitutes much of the PM-10 sample mass, it does not scatter light very effectively. This behavior also tends to inflate the PM-2.5/PM-10 ratio given in the last column of Table 2.

The logging mode of the DustTRAK provided 6-sec average concentration values for each of the test runs. After subtracting out the minimum concentration recorded by the DustTRAK, which was assumed to be background, these values were used to find an average concentration value from the beginning of the test run to the end of a selected 10-m wind speed. The average concentration along with the tunnel volumetric flow rate, the length of time from the beginning of the test until the end of testing at the specified wind speed, and the exposed test surface area were used to determine the erosion potential for that wind speed. In order to account for the reduced capability of the DustTRAK to detect the coarse PM-10 mode, the erosion potential values estimated from the time-integrated DustTRAK PM-10 concentration for each wind speed were multiplied by the ratio of the effluent sampler average PM-10 concentration to the DustTRAK average PM-10 concentration.

Table 3 presents calculated values of PM-10 and TP erosion potential for each test run. Average erosion potential values for the three test periods are given in Table 4. Although the same incremental pressure drops for the wind tunnel centerline wind speed were used for the three test periods, changes in the roughness height of the surface over the three-month period resulted in increases in the equivalent 10-m wind speeds. Higher maximum wind speeds than shown in Table 4 were reached in some runs during the June test period, but they were not consistent enough to provide for a representative average value.

Table 2. Wind Tunnel Test Results: Average Concentrations

Date	Run no.	Duration (min)	Average effluent PM-10 conc. (mg/m^3)	Background PM-10 conc. (mg/m^3)	Net[a] PM-10 conc. (mg/m^3)	TP conc. (mg/m^3)	Average DustTRAK PM-10 conc. (mg/m^3)	Ratio of effluent/ DustTRAK PM-10 conc.	Average DustTRAK PM-2.5 conc. (mg/m^3)	Ratio of DustTRAK PM-2.5 conc./ PM-10 conc.
4/7/00	CB-1	126	0.262	0.079	0.183	0.458	0.038	6.89	0.022	0.58
4/8/00	CB-2	108	0.119	0.057	0.063	0.258	0.017	7.14	0.016	0.97
4/8/00	CB-3	111	0.153	0.057	0.097	0.257	0.022	6.97	0.018	0.81
4/9/00	CB-4	100	0.061	0.010	0.051	0.122	0.010	5.90	0.005	0.48
4/10/00	CB-5	99	0.027	0.021	0.006	0.068	0.010	2.63	0.005	0.45
4/11/00	CB-6	96	0.029	0.023	0.006	0.092	0.023	1.27	0.021	0.92
5/2/00	CB-7	94	0.086	0.040	0.046	0.447	0.028	3.11	0.019	0.69
5/2/00	CB-8	103	0.132	0.040	0.092	0.908	0.028	4.65	0.013	0.46
5/3/00	CB-9	88	0.084	0.028	0.056	0.337	0.021	3.96	0.011	0.54
6/21/00	CB-10	114	0.241	0.029	0.211	3.504	0.034	7.15	0.010	0.31
6/21/00	CB-11	77	0.134	0.029	0.105	0.806	0.013	10.06	0.012	0.92
6/22/00	CB-12	92	0.118	0.029	0.089	1.447	0.019	6.13	0.010	0.52
6/22/00	CB-13	90	0.047	0.028	0.018	0.091	0.010	4.84	0.007	0.67
6/23/00	CB-14	88	0.031	0.039	<0.001	0.221	0.009	3.61	0.006	0.65
6/23/00	CB-15	89	0.036	0.039	<0.001	0.371	0.010	3.64	0.006	0.57

[a] Net = Average effluent concentration—Background concentration.

Table 3. Wind Tunnel Test Results: Erosion Potentials

Date	Run no.	Average roughness height, Z_0 (cm)	Maximum wind speed (mph) at tunnel CL[a]	Equivalent maximum wind speed (mph) at 10-m height[b]	Corresponding friction velocity[b] (cm/s)	Erosion potential/loss[c] (g/m^2) TP	PM-10	Loss ratio (PM-10/TP)
4/7/00	CB-1	0.85	40.3	97.6	244.7	1.33	0.65	0.483
4/8/00	CB-2	0.66	40.3	97.6	244.7	0.61	0.19	0.311
4/8/00	CB-3	0.89	40.3	97.6	244.7	0.62	0.30	0.483
4/9/00	CB-4	1.65	39.7	110.1	301.0	0.31	0.14	0.454
4/10/00	CB-5	1.76	40.3	111.9	305.8	0.13	0.02	0.127
4/11/00	CB-6	0.92	40.3	111.9	305.8	0.18	0.02	0.087
5/2/00	CB-7	1.10	37.0	100.5	271.4	1.07	0.12	0.113
5/2/00	CB-8	1.31	40.3	109.6	295.8	2.50	0.26	0.106
5/3/00	CB-9	1.57	37.2	101.2	273.3	0.76	0.14	0.182
6/21/00	CB-10	3.00	38.6	138.3	425.9	11.09	0.67	0.061
6/21/00	CB-11	3.12	29.2	104.7	322.4	1.67	0.23	0.135
6/22/00	CB-12	2.91	35.8	128.4	395.3	3.65	0.23	0.063
6/22/00	CB-13	3.17	39.3	145.2	452.5	0.16	0.05	0.295
6/23/00	CB-14	3.16	34.8	128.6	400.6	0.45	–0.02	–0.041
6/23/00	CB-15	3.32	37.5	138.8	432.4	0.83	–0.01	–0.007

[a] Average maximum wind speed at tunnel centerline (CL) for all three tests.
[b] Average roughness height over three runs used to calculate equivalent 10-m wind speed and friction velocity.
[c] Calculated using net mass and the alternative method referred to on page 8 and described in more detail in Appendix D.

Table 4. DustTRAK Average PM-10 Erosion Potentials

April 2000				May 2000		June 2000			
Burned		Unburned		Burned		Burned		Unburned	
Wind speed at 10-m height	Average erosion potential (g/m^2)	Wind speed at 10-m height	Average erosion potential (g/m^2)	Wind speed at 10-m height	Average erosion potential (g/m^2)	Wind speed at 10-m height	Average erosion potential (g/m^2)	Wind speed at 10-m height	Average erosion potential (g/m^2)
12	0.000	14	0.000	14	0.000	18	0.000	19	0.000
24	0.001	28	0.000	28	0.001	36	0.001	38	0.000
36	0.002	42	0.001	41	0.002	54	0.002	56	0.001
48	0.007	56	0.003	55	0.005	72	0.006	75	0.002
61	0.011	70	0.004	69	0.009	90	0.012	94	0.003
73	0.018	83	0.006	83	0.014	109	0.020	113	0.005
85	0.029	97	0.009	96	0.022	127	0.042	132	0.007
97	0.057	111	0.013	110	0.033				

Figure 6 shows the average erosion potential value versus wind speed (mph) at a 10-m height after adjustment of the DustTRAK PM-10 concentrations. The exponential rate of increase of the erosion potential with wind speed can be seen. It is evident that above 40 mph, there is a higher rate of increase of PM-10 erosion potential with 10-m wind speed.

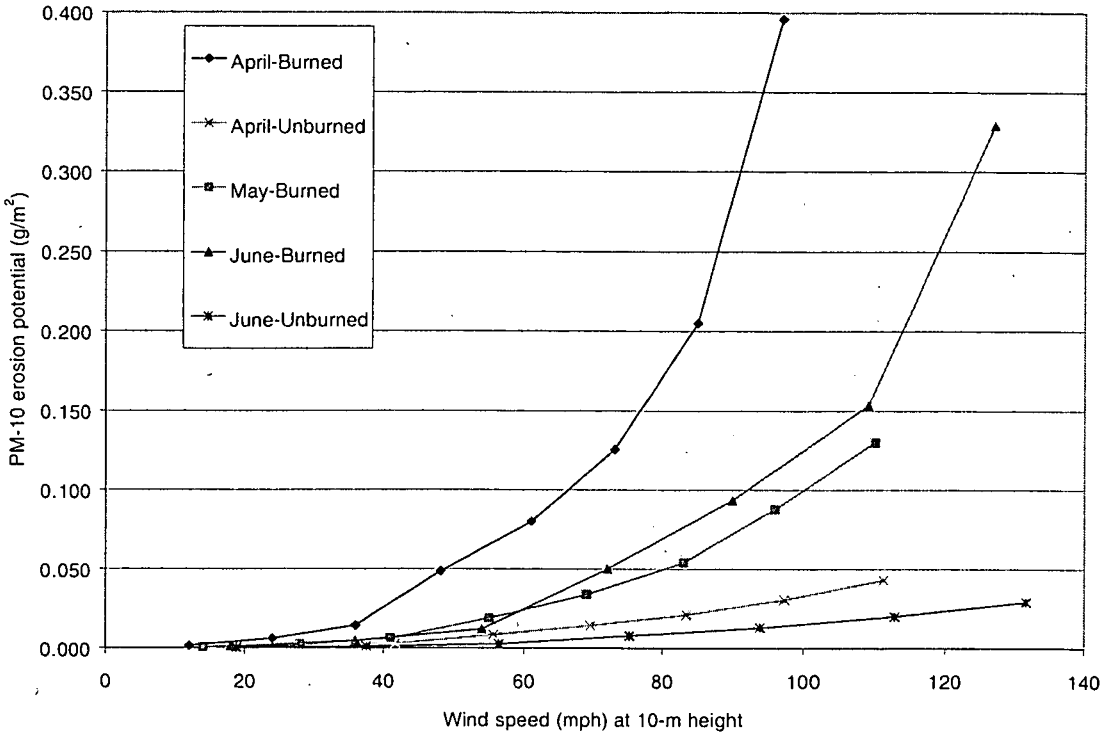


Figure 6. PM-10 Erosion Potential vs. 10-m Wind Speeds As Determined From DustTRAK Data. (Erosion potential values adjusted based on ratio of effluent concentration/DustTRAK concentration)

Based on the data available, a linear interpretation was made between consecutive data points (above and below the desired wind speed value) to determine a DustTRAK erosion potential value at a 95-mph wind speed and also for the maximum wind speed during each test run. The ratio of these two values was then used to adjust the erosion potential (see Table 3) to a 95-mph wind speed at a 10-m height. The 95-mph PM-10 erosion potentials for all the test runs are presented in Table 5. The resulting erosion potential history can be seen in Figure 7.

From Figure 7, the PM-10 erosion potential of the burned area appears to decay in time with the regrowth of vegetation, although the average erosion potential for the May tests is similar to that found for the June tests. The average erosion potential for the May test would have been higher except for the effect of higher soil moisture in May as compared to the other test periods. The PM-10 erosion potential for the unburned grassland remains consistently low, in the range of 0.05 g/m^2, as seen from April tests CB-4, 5, 6 and June tests CB-13, 14, 15.

Table 5. PM-10 Erosion Potentials at 95-mph

Date	Run no.	PM-10 erosion potential (g/m^2)
4/7/00	CB-1	0.59
4/8/00	CB-2	0.17
4/8/00	CB-3	0.28
4/9/00	CB-4	0.10
4/10/00	CB-5	0.01
4/11/00	CB-6	0.01
5/2/00	CB-7	0.10
5/2/00	CB-8	0.18
5/3/00	CB-9	0.12
6/21/00	CB-10	0.17
6/21/00	CB-11	0.18
6/22/00	CB-12	0.07
6/22/00	CB-13	0.02
6/23/00	CB-14	< 0.02
6/23/00	CB-15	< 0.02

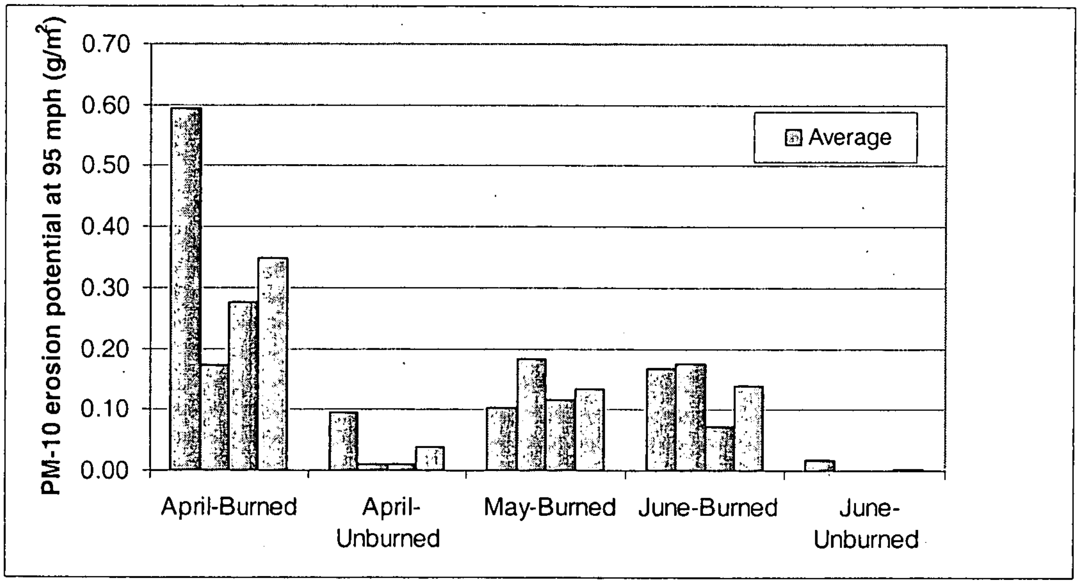


Figure 7. Erosion Potential History at 95-mph Wind Speed

24

Section 4.
Results of Laboratory Tests

Laboratory tests of surface soil samples were performed (a) to characterize the soil emission potential as a function of moisture content, and (b) to determine the PM-10 emission components (organic and elemental carbon).

4.1 Dustiness Testing

Dustiness testing was performed on samples of surface soil to characterize the potential for release of airborne PM, specifically the PM-10 and PM-2.5 components, when the dry soil is disturbed. Dustiness tests were also run under varying soil moisture levels to provide information on the mitigative effect of soil moisture in reducing PM-10 and PM-2.5 emissions.

4.1.1 Sample Preparation

The six surface soil samples collected from the Rocky Flats prescribed burn area were analyzed for moisture content prior to dustiness testing. The samples were considered to be representative of the controlled burn area. Because the samples were collected on different dates and times, they represented different moisture levels, as shown in Table 6. Except for the samples collected on April 10, 2000, the moisture levels indicated that the surface soil was relatively dry.

Table 6. Moisture Levels of "Burned Area" Surface Soil Samples

Sample label	Location of sample collection	Date collected	Current moisture (%)
4/7 Surface Soil "D"	Adjacent to test plot CB-1A	4/7/00	1.4
4/8 Adjacent to CB-2	Adjacent to test plot CB-3B	4/8/00	2.3
4/10 Burned Area #3	Southwest corner of burned area	4/10/00	7.6
4/10 Burned Area #4	Southwest corner of burned area	4/10/00	17.5
5/3 Burned Area #1	Adjacent to test plots CB-7,8,9	5/3/00	1.8
5/3 Burned Area #2	Adjacent to test plots CB-7,8,9	5/3/00	1.4

When the individual soil samples with low moisture contents (in the range of 1.4% to 2.3%) were tested for PM-10 dustiness, the results given in Table 7 were obtained. These initial tests also showed variations in the dustiness index (by a factor of 3) within only a 1 percent range of moisture content. This may have reflected differences in soil texture resulting from differences in compaction. As a result, it was decided that the samples should be composited to provide better representation of surface soil conditions in the

26

prescribed burn area, for purposes of developing a relationship between soil dustiness and moisture content.

Table 7. Results of Preliminary PM-10 Dustiness Tests

Test ID	Sample label	Moisture (%)	Mass poured (g)	Mass collected (mg)	Dustiness index (mg/kg)
1	5/3 Burned Area #2	1.4	635.0	3.075	4.8
2	5/3 Burned Area #1	1.8	526.0	4.723	9.0
3	4/7 Surface Soil "D"	1.4	490.3	4.293	8.8
4	4/8 Adjacent to Plot CB-2	2.3	489.5	8.157	16.7

The procedure for compositing the soil samples was to (a) pass each sample through a 1-cm sieve in order to eliminate large rocks and sticks that might be present, as is standard procedure for dustiness testing, (b) dry each sample in a 110°C oven overnight, and (c) combine all six samples (in equal amounts) into one composite sample and seal in an air tight container until ready to be used. The composite sample was then split into as many subsamples as needed for testing and the subsamples were moisturized to the percentages desired for testing.

The moisture levels selected for dustiness testing were 0%, 2%, 4%, 6%, and 8%. The following procedure was used for moisturizing subsamples that had been oven dried:

1. Tare weigh a clean pan.
2. Record the weight of the pan and dry sample.
3. Determine the weight of the sample.
4. Calculate the amount of water (g) to be added to the sample, using the sample weight and the desired moisture content.

   Example: Desired moisture content = 4.0%
   Pan tare weight = 18.6 g   Pan + Sample = 518.6 g   Sample = 500.0 g
   Moisture to be added: $\frac{500.0\text{ g}}{(100\%-4\%)} = \frac{x\text{ g}}{4\%}$ x = 20.8 g

5. Spray the sample, weighing it on a balance, until the desired weight is observed.
6. Return sample to sealed container for at least 6 hrs to ensure that moisture is evenly distributed.

The scope of work required dustiness characterization of the soil samples for both PM-10 and PM-2.5. The dustiness tests for PM-10 were run first, and then the samples were poured a second time for PM-2.5 dustiness characterization. A total of ten tests were performed, not including blank runs that were used to account for the effects of filter handling. A total of three filters were used for blank runs during the testing period. The order of testing is listed below in Table 8.

Table 8. Dustiness Test Matrix

Moisture level	PM-10 Dustiness test	PM-2.5 Dustiness test
0%	1	6
2%	2	7
4%	3	8
6%	4	9
8%	5	10

4.1.2 Results of Dustiness Testing

The results of the PM-10 and PM-2.5 dustiness tests are given in Table 9. The PM-10 dustiness was found to decrease with soil moisture content above 2 percent, as expected. This result is illustrated in Figure 8. However, for bone dry soil, the PM-10 dustiness is lower than at 2 percent moisture. This likely reflects the tendency of soil particles to bond because of electrostatic charging at very low moisture levels.

The PM-2.5 dustiness appears to be relatively independent of moisture content. There is an apparent anomaly at the 8 percent moisture level because the PM-2.5 dustiness index exceeds the PM-10 dustiness index. This may reflect the drying of the sample during the three pours that were necessary to quantify the dustiness of this sample.

Table 9. PM-10 and PM-2.5 Dustiness Test Results

Approximate Moisture (%)	PM-10 Test ID	PM-10 Mass poured (g)	PM-10 Mass collected (mg)	PM-10 Dustiness index (mg/kg)	PM-2.5 Test ID	PM-2.5 Mass poured (g)	PM-2.5 Mass collected (mg)	PM-2.5 Dustiness index (mg/kg)
0	6	428.4	2.296	5.4	11	646.7	1.519	2.3
2	7	293.0	7.012	29.3	12	503.1	0.841	1.7
4	8	211.9	5.182	24.5	13	465.2	3.288	7.1
6	9	213.8	2.551	11.9	14	444.6	1.624	3.7
8	10	622.3	0.485	0.8	17	647.7	3.014	4.7

Test 15—unusable due to filter edge tearing.
Test 16 and 18—blank test runs.

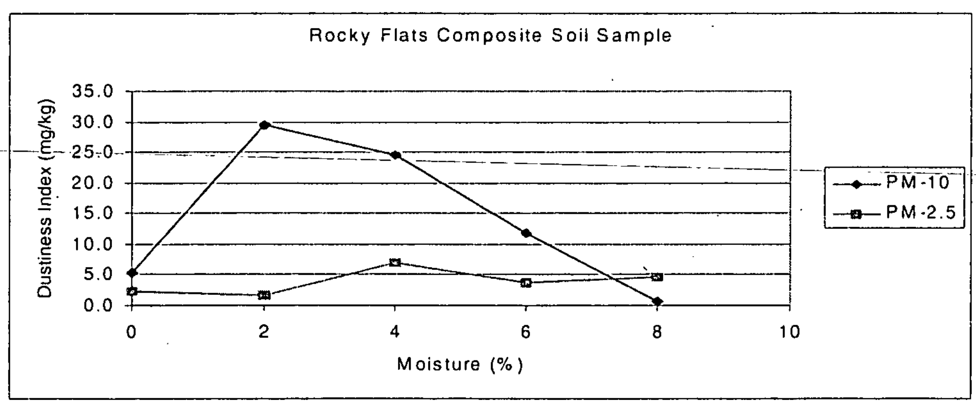


Figure 8. Soil Dustiness Index vs. Soil Moisture Content

4.2 Carbon Analysis

Table 10 presents the carbon analysis results of the PM-10 filters from each test run. All analysis results were corrected for EC and OC present on blank filters that were not exposed to airflow. The EC and OC masses on the blank-corrected background filters were also adjusted to the same run time as used for the filters exposed to wind tunnel emissions.

Table 11 gives the abundance of EC and OC in the PM-10 that was generated by wind erosion of each test surface (after subtraction of the background contribution). The EC and OC abundance in PM-10 emissions for each test run are shown graphically in Figure 10.

Several observations can be made from examination of Figure 9. First, both EC and OC are present to a much greater extent in PM-10 emissions from the burned area as compared to PM-10 emissions from adjacent unburned grassland. Second, EC in the emissions from the burned area tends to decrease as vegetation is reestablished, but OC does not. The higher emissions from the June tests of the burned area (CB-10 through CB-12) reflect the much drier conditions than had occurred in earlier testing. The negative values shown in Figure 10 for five of the six tests on the unburned, grassy area indicate inadequate treatment for blanks.

Clearly, OC dominates the carbon constituent of PM-10 for background samples and unburned area emissions. In contrast, the EC emissions from soil erosion of the prescribed burn area represent a much larger fraction of the total PM-10 emissions. Moreover, the EC emissions decrease from April to May to June (i.e., 770 μg/filter in April, 270 μg/filter in May, and 136 μg/filter in June).

Table 10. Carbon Analysis Results

Run	Emission sampler: PM-10 mass collected on filter (mg)	Emission sampler: Sampler run time (min)	Emission sampler: Blank corrected[a] organic carbon (μg/filter)	Emission sampler: Blank corrected[a] elemental carbon (μg/filter)	Background sampler: PM-10 mass collected on filter[c] (mg)	Background sampler: Sampler run time (min)	Background sampler: Adjusted net mass[b] (mg)	Background sampler: Adjusted[b] blank corrected[a] organic carbon[c] (μg/filter)	Background sampler: Adjusted[b] blank corrected[a] elemental carbon[c] (μg/filter)
CB-1	36.85	126	3042.6	2328.4	12.55	141	11.21	879.19	329.76
CB-2	14.05	108	2254.8	1599.2	15.72	249	6.82	1079.94	406.94
CB-3	18.75	111	2765.1	1547.1	15.72	249	7.01	1109.94	418.24
CB-4	6.35	100	996.6	–38.9	0.92	104	0.89	91.79	–28.59
CB-5	2.50	99	389.7	–26.3	2.15	101	2.11	259.27	25.40
CB-6	2.65	96	28.7	–10.3	2.70	112	2.31	203.24	48.31
CB-7	9.15	94	1912.9	769.5	9.80	217	4.25	737.97	88.55
CB-8	15.35	103	3261.1	1076.8	9.80	217	4.65	808.63	97.03
CB-9	8.40	88	956.4	784.0	2.97	93	2.82	345.95	220.01
CB-10	33.70	114	5978.7	802.6	7.90	199	4.53	603.86	115.35
CB-11	14.30	77	1717.7	689.5	7.90	199	3.06	407.87	77.92
CB-12	14.95	92	2337.9	267.0	4.58	98	4.29	378.81	10.43
CB-13	7.40	90	2004.2	50.8	4.52	100	4.07	828.50	86.55
CB-14	5.75	88	593.7	216.2	5.58	97	5.06	630.71	162.18
CB-15	6.30	89	1542.7	430.7	5.58	97	5.12	637.87	164.02

[a] Blank corrected values based on average of all field and lab blanks.
[b] Background values time-weighted to reflect mass seen during emission sampler run time.
[c] Mass collected on background filter assumed to be half PM-10.

Table 11. Carbon Contribution to PM-10 Mass from Wind Erosion Test

Run	Net values								
	PM-10 mass (mg)	Organic carbon (μg/ filter)	Organic carbon (mg)	%	Elemental carbon (μg/ filter)	Elemental carbon (mg)	%	Total carbon (mg)	%
CB-1	25.64	2163.43	2.16	8.44	1998.67	2.00	7.80	4.16	16.2
CB-2	7.23	1174.88	1.17	16.25	1192.29	1.19	16.49	2.37	32.7
CB-3	11.74	1655.18	1.66	14.10	1128.89	1.13	9.62	2.78	23.7
CB-4	5.46	904.83	0.90	16.57	–10.28	–0.01	–0.19	0.89	16.4
CB-5	0.39	130.45	0.13	33.23	-51.67	–0.05	–13.16	0.08	20.1
CB-6	0.34	–174.52	–0.17	–51.98	–58.58	–0.06	–17.45	–0.23	–69.4
ssssCB-7	4.90	1174.95	1.17	23.95	680.98	0.68	13.88	1.86	37.8
CB-8	10.70	2452.49	2.45	22.92	979.80	0.98	9.16	3.43	32.1
CB-9	5.58	610.47	0.61	10.93	564.02	0.56	10.10	1.17	21.0
CB-10	29.17	5374.86	5.37	18.42	687.28	0.69	2.36	6.06	20.8
CB-11	11.24	1309.85	1.31	11.65	611.61	0.61	5.44	1.92	17.1
CB-12	10.66	1959.11	1.96	18.39	256.60	0.26	2.41	2.22	20.8
CB-13	3.33	1175.72	1.18	35.33	–35.72	–0.04	–1.07	1.14	34.3
CB-14	0.69	–36.99	–0.04	–5.34	54.05	0.05	7.81	0.02	2.5
CB-15	1.18	904.85	0.90	76.37	266.71	0.27	22.51	1.17	98.9

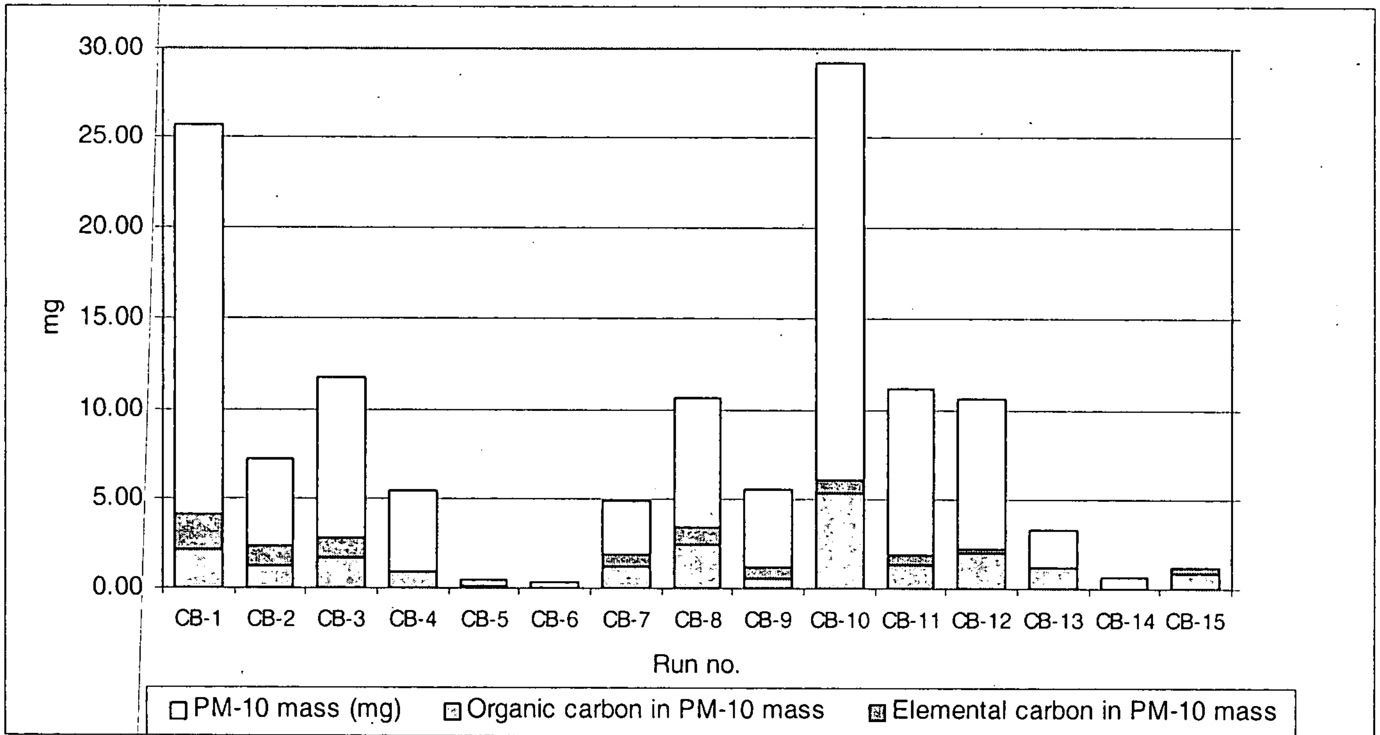


Figure 9. Abundance of EC and OC in PM-10 from Erosion Surface

Section 5. Conclusions

During the three months of testing, wind erosion particulate emissions from the prescribed burn area at Rocky Flats were found to be much less than has been previously observed by MRI on disturbed land at other test locations in the area. The burned grassland was observed to retain many of the characteristics that limit wind erosion—including soil crusts, rocks that protect the surface soil, and grass clumps that will revegetate.

PM-10 erosion potentials from the prescribed burn areas were always somewhat greater than for unburned areas, even for the June tests—approximately 2½ months after the burn. Although the differences were reduced as vegetation was re-established, they were still evident. This was clearly due to the protection afforded by the dead grass thatch that completely covered the unburned areas, but had been destroyed by the fire on the burned areas. Even though the burned areas had revegetated to a large extent with tall, thin plants by the June test period, bare soil that constituted an emission source that was still visible between the revegetating plants.

During the May tests, the mitigative effects of soil moisture were evident at moderate temperatures. This was confirmed by laboratory dustiness tests. However, because the soil surface dries quickly in the relatively low humidity environment of Rocky Flats, especially at warm temperatures, the mitigative effect of rainfall is usually transient.

Although the results of the wind erosion tests on the Rocky Flats prescribed burn area did not show a clearly evident threshold velocity for the onset of wind erosion, PM-10 erosion potentials above 40 mph (at a height of 10 m) were observed to increase at a higher rate with increasing wind speed. Emission spikes occurred as the wind speed was raised in 5-mph increments at the tunnel centerline. Spikes for lower velocity winds were smaller and quickly decayed in time as the wind speed was held to a constant value for a period of 2 to 8 min. As the wind speed increased to higher plateaus, the spikes were larger and decayed at a slower rate. These observed phenomena indicate the contribution of multiple release mechanisms to the overall wind erosion dynamics.

Section 6. References

Baxter, T.E., D.D. Lane, C. Cowherd, Jr., F. Pendleton. "Calibration of a Cyclone for Monitoring Inhalable Particulate". *Jour. Environ. Engineering*, 112(3), pp. 468-478. 1986.

Cowherd, C., Jr., G. E. Muleski, P.J. Englehart, D.A. Gillette. *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites*. EPA/600/8-85/002. USEPA, Washington, DC. 1985.

Cowherd, Chatten, Jr. *Background Document for AP-42 Section 11.2.7 on Industrial Wind Erosion*. EPA Contract No. 68-02-4395, Midwest Research Institute. July 1988.

Cowherd, C. Jr., M.A. Grelinger, P.J. Englehart, R.F. Kent, K.F. Wong. Apparatus and Methodology for Predicting the Dustiness of Materials. Am Ind. Hyg. Assoc. Jour. (50), pp. 123-130. 1989.

Gillette, Dale. "Tests with a Portable Wind Tunnel for Determining Wind Erosion Threshold Velocities." *Atmos. Environ.* 12:2309. 1978.

Huntzicker, J.J., R.L. Johnson, J.J. Shah, R.A. Cary. "Analysis of Organic and Elemental Carbon in Ambient Aerosol by a Thermal-Optical Method," in *Particulate Carbon: Atmospheric Life Cycle*, pp 79-88. G.T. Wolff, R.L. Klimisch, Eds., Plenum Press, New York, NY. 1982.

Ower, E., R.C. Pankhurst. *The Measurement of Air Flow*. Pergamon Press, London. 1969.

U.S. Environmental Protection Agency. *National Technical Guidance Series Air Pathway Analysis Procedure for Superfund Applications*. Vol. II: *Estimates of Baseline Air Emissions at Superfund Sites*. EPA-450/1-89-002a. 1989.

U.S. Environmental Protection Agency. "Compilation of Air Pollutant Emissions Factors", AP-42, Fifth Edition, Supplements A-F, Volume I: *Stationary Point and Area Sources*. Research Triangle Park, NC. 2000.

Watson, J.G., J. Chow. "Particle and Gas Measurement on Filters," in *Sampling of Environmental Materials for Trace Analysis* (edited by B. Markert), pp. 83-115. VCH Publisher, Weinheim, New York, Tokyo. 1994.

Appendix A

Results of Gravimetric Analysis

Table A-1. Cyclone Back-up Filter weights (mg)

Date	Run no.	Filter no.	Tare weight	Final weight	Blank Correction	Corrected net weight	Cyclone catch (g)	Filter/ Cyclone
4/7/00	CB-1	0012002	3599.95	3636.80	–0.54	37.39	0.0279	1.3400
4/8/00	CB-2	0012006	3595.85	3609.90	–0.54	14.59	0.0170	0.8580
4/8/00	CB-3	0012007	3578.25	3597.00	–0.54	19.29	0.0130	1.4836
4/9/00	CB-4	0012013	3584.75	3591.10	–0.54	6.89	0.0069	0.9980
4/10/00	CB-5	0012017	3597.65	3600.15	–0.54	3.04	0.0046	0.6601
4/11/00	CB-6	0012021	3591.15	3593.80	–0.54	3.19	0.0068	0.4686
5/2/00	CB-7	0012028	3293.05	3302.20	0.00	9.15	0.0384	0.2383
5/2/00	CB-8	0012029	3307.00	3322.35	0.00	15.35	0.0906	0.1694
5/3/00	CB-9	0012033	3303.65	3312.05	0.00	8.40	0.0252	0.3333
6/21/00	CB-10	0012042	3514.90	3548.60	2.63	31.07	0.4213	0.0737
6/21/00	CB-11	0012044	3507.90	3522.20	2.63	11.67	0.0586	0.1991
6/22/00	CB-12	0012049	3497.90	3512.85	2.63	12.32	0.1384	0.0890
6/22/00	CB-13	0012054	3295.50	3302.90	2.63	4.77	0.0045	1.0593
6/23/00	CB-14	0012056	3290.55	3296.30	2.63	3.12	0.0189	0.1649
6/23/00	CB-15	0012057	3317.40	3323.70	2.63	3.67	0.0337	0.1088

Table A-2. Upwind/ Background Filter weights (mg)

Date	Run no.	Filter no.	Tare weight	Final weight	Blank Correction	Corrected net weight	Duration (min)	Sampler flow rate (cfm)
4/7/00	CB-1	0012001	3588.85	3613.95	–0.54	25.64	143	40
4/8/00	CB-2,3	0012005	3596.80	3628.25	–0.54	31.99	249	40
4/9/00	CB-4	0012011	3577.55	3579.40	–0.54	2.39	104	40
4/10/00	CB-5	0012016	3574.40	3578.70	–0.54	4.84	101	40
4/11/00	CB-6	0012020	3601.35	3606.75	–0.54	5.94	112	40
5/2/00	CB-7,8	0012027	3300.20	3319.80	0.00	19.60	217	40
5/3/00	CB-9	0012032	3308.65	3314.60	0.00	5.95	93	40
6/21/00	CB-10,11	0012043	3518.50	3534.30	2.63	13.17	199	40
6/22/00	CB-12	0012048	3513.95	3523.10	2.63	6.52	98	40
6/22/00	CB-13	0012053	3314.80	3323.85	2.63	6.42	100	40
6/23/00	CB-14,15	0012055	3306.60	3317.75	2.63	8.52	97	40

Table A-3. Blank Filter weights (mg)

Date	Run No.	Filter No.	Tare weight	Final weight	Net weight
4/7/00	CB-1	0012003	3614.25	3613.75	–0.50
4/7/00	CB-1	0012004	3611.15	3610.95	–0.20
4/8/00	CB-2,3	0012009	3580.95	3579.90	–1.05
4/8/00	CB-2,3	0012010	3579.60	3578.95	–0.65
4/9/00	CB-4	0012014	3578.20	3577.45	–0.75
4/9/00	CB-4	0012015	3556.35	3556.30	–0.05
4/10/00	CB-5	0012018	3599.55	3598.80	–0.75
4/10/00	CB-5	0012019	3601.15	3601.05	–0.10
4/11/00	CB-6	0012022	3601.65	3601.10	–0.55
4/11/00	CB-6	0012023	3570.75	3570.00	–0.75
4/11/00	CB-6	0012025	3588.95	3588.40	–0.55
5/2/00	CB-7,8	0012030	3304.60	3304.50	–0.10
5/2/00	CB-7,8	0012031	3284.35	3284.20	–0.15
5/3/00	CB-9	0012034	3301.05	3301.30	0.25
6/21/00	CB-10,11	0012045	3509.00	3511.65	2.65
6/21/00	CB-10,11	0012046	3519.10	3522.50	3.40
6/22/00	CB-12,13	0012050	3517.60	3520.25	2.65
6/22/00	CB-12,13	0012052	3302.90	3305.70	2.80
6/23/00	CB-14,15	0012058	3338.70	3341.60	2.90
6/23/00	CB-14,15	0012059	3320.10	3322.75	2.65
6/23/00	CB-14,15	0012060	3324.85	3327.30	2.45
6/23/00	CB-14,15	0012061	3298.75	3301.00	2.25
6/23/00	CB-14,15	0012062	3260.65	3262.60	1.95

April average blank filter weight = –0.54 mg
May average blank filter weight = 0.00 mg
June average blank filter weight = 2.63 mg

Table A-4. Dustiness Test Filter weights (mg)

Test ID	Filter no.	Tare weight	Final weight	Net mass collected	Blank corrected net weight
1	0017001	145.040	148.137	3.097	3.075
2	0017002	144.962	149.707	4.745	4.723
3	0017003	145.868	150.183	4.315	4.293
4	0017004	145.430	153.609	8.179	8.157
5	0017005	146.360	146.382	0.022	
6	0017006	144.423	146.806	2.383	2.296
7	0017007	145.000	152.099	7.099	7.012
8	0017008	143.781	149.050	5.269	5.182
9	0017009	145.180	147.818	2.638	2.551
10	0017010	145.027	145.599	0.572	0.485
11	0017011	145.122	146.728	1.606	1.519
12	0017012	145.262	146.190	0.928	0.841
13	0017013	144.439	147.814	3.375	3.288
14	0017014	143.437	145.148	1.711	1.624
15	0017015	144.367	144.829	0.462	0.375
16	0017016	144.555	144.608	0.053	
17	0017017	144.395	147.496	3.101	3.014
18	0017018	144.297	144.418	0.121	

Appendix B

Carbon Analysis Data

Table B-1. Carbon Analysis Data
Desert Research Institute Results

QID	Filter ID	Run/Description	Date	OETF	OCTC	OCTU	ECTC	ECTU	TCTC	TCTU	DEPAREA
12001	0012001	CB-1/Background	4/7/00		3065.80	219.50	797.50	59.50	3863.30	276.00	406.0
12002	0012002	CB-1/Test	4/7/00	m2	4140.70	278.90	2387.90	162.80	6528.50	433.80	406.0
12003	0012003	CB-1/Field Blank	4/7/00		1018.90	127.60	12.80	26.90	1031.80	141.90	406.0
12004	0012004	CB-2/Field Blank	4/7/00		859.50	123.00	0.00	25.70	859.50	137.20	406.0
12005	0012005	CB-2&3/Background	4/8/00	m2	6077.80	391.60	1935.90	132.90	8013.70	524.90	406.0
12006	0012006	CB-2/Test	4/8/00		3352.90	235.00	1658.70	114.60	5011.60	342.60	406.0
12007	0012007	CB-3/Test	4/8/00		3863.20	263.20	1606.60	111.20	5469.80	369.90	406.0
12009	0012009	CB-3/Field Blank	4/8/00		694.70	119.00	0.00	25.70	694.70	133.40	406.0
12010	0012010	CB-3/Field Blank	4/8/00		782.20	121.00	0.00	25.70	782.20	135.30	406.0
12011	0012011	CB-4/Background	4/9/00		1289.00	136.60	0.00	25.70	1289.00	150.20	406.0
12012	0012012	Carbon Analysis Blank	Apr Test Period		927.80	124.90	1.40	25.70	929.20	139.00	406.0
12013	0012013	CB-4/Test	4/9/00		2094.70	170.50	20.60	28.70	2115.30	184.20	406.0
12014	0012014	CB-4/Field Blank	4/9/00		860.80	123.10	37.50	34.70	898.30	138.20	406.0
12015	0012015	CB-4/Field Blank	4/9/00		1091.20	129.80	92.30	62.90	1183.40	146.60	406.0
12016	0012016	CB-5/Background	4/10/00		1627.10	149.70	111.30	73.90	1738.50	167.50	406.0
12017	0012017	CB-5/Test	4/10/00		1487.80	144.10	33.20	33.00	1521.00	158.70	406.0
12018	0012018	CB-5/Field Blank	4/10/00		802.60	121.50	19.60	28.50	822.20	136.30	406.0
12019	0012019	CB-5/Field Blank	4/10/00		1030.80	127.90	47.80	39.30	1078.60	143.30	406.0
12020	0012020	CB-6/Background	4/11/00		1572.30	147.50	172.20	110.20	1744.50	167.80	406.0
12021	0012021	CB-6/Test	4/11/00		1126.80	131.00	49.20	40.00	1176.00	146.40	406.0
12022	0012022	CB-6/Field Blank	4/11/00		723.40	119.60	0.00	25.70	723.40	134.00	406.0
12023	0012023	CB-6/Field Blank	4/11/00		1031.40	128.00	20.70	28.80	1052.10	142.50	406.0
12024	0012024	Carbon Analysis Blank	Apr Test Period		1057.90	128.80	13.00	27.00	1070.90	143.10	406.0
12025	0012025	CB-6/Field Blank	4/11/00		1275.80	136.10	32.80	32.80	1308.60	150.90	406.0
12027	0012027	CB-7&8/Background	5/2/00		4505.30	299.70	468.30	40.70	4973.60	340.40	406.0
12028	0012028	CB-7/Test	5/2/00		3011.00	216.60	829.00	61.50	3840.00	274.70	406.0
12029	0012029	CB-8/Test	5/2/00		4359.20	291.30	1136.30	80.70	5495.50	371.40	406.0
12030	0012030	CB-7&8/Field Blank	5/2/00		750.60	120.30	5.20	25.90	755.80	134.70	406.0
12031	0012031	CB-7&8/Field Blank	5/2/00		696.50	119.00	0.00	25.70	696.50	133.40	406.0
12032	0012032	CB-9/Background	5/3/00		1829.30	158.40	524.50	43.70	2353.80	195.50	406.0
12033	0012033	CB-9/Test	5/3/00		2054.50	168.60	843.50	62.30	2898.00	223.10	406.0

Table B-1. Carbon Analysis Data Desert Research Institute Results (Continued)

QID	Filter ID	Run/Description	Date	OETF	OCTC	OCTU	ECTC	ECTU	TCTC	TCTU	DEPAREA
12034	0012034	CB-9/Field Blank	5/3/00		837.90	122.50	114.50	75.80	952.40	139.70	406.0
12035	0012035	Carbon Analysis Blank	May Test Period		739.40	120.00	38.20	35.00	777.60	135.20	406.0
12037	0012037	Carbon Analysis Blank	May Test Period		963.70	125.90	204.10	129.60	1167.70	146.10	406.0
12040	0012040	Carbon Analysis Blank	May Test Period		2231.20	177.00	334.10	34.20	2565.30	206.00	406.0
12042	0012042	CB-10/Test	6/21/00	m2	7076.80	451.10	862.10	63.50	7938.90	520.20	406.0
12043	0012043	CB-10&11/Background	6/21/00		3206.30	227.10	462.20	40.40	3668.50	265.00	406.0
12044	0012044	CB-11/Test	6/21/00		2815.80	206.40	749.00	56.60	3564.80	259.30	406.0
12046	0012046	CB-10&11/Field Blank	6/21/00		1430.90	141.90	0.00	25.70	1430.90	155.30	406.0
12047	0012047	Carbon Analysis Blank	Jun Test Period		2275.70	179.10	332.60	34.10	2608.40	208.20	406.0
12048	0012048	CB-12/Background	6/22/00		1905.10	161.80	81.70	57.00	1986.90	178.30	406.0
12049	0012049	CB-12/Test	6/22/00		3436.00	239.50	326.50	204.80	3762.50	270.30	406.0
12050	0012050	CB-12/Field Blank	6/22/00		1237.60	134.80	166.40	106.70	1403.90	154.30	406.0
12051	0012051	Carbon Analysis Blank	Jun Test Period		1139.10	131.40	125.50	82.20	1264.60	149.40	406.0
12052	0012052	CB-12&13/Field Blank	6/22/00		1325.60	137.90	31.60	32.40	1357.20	152.60	406.0
12053	0012053	CB-13/Background	6/22/00		2939.20	212.80	251.80	158.80	3191.00	238.80	406.0
12054	0012054	CB-13/Test	6/22/00		3102.30	221.50	110.30	73.30	3212.60	239.90	406.0
12055	0012055	CB-14&15/Background	6/23/00		2488.50	189.60	417.00	38.10	2905.50	223.50	406.0
12056	0012056	CB-14/Test	6/23/00		1691.80	152.40	275.70	173.50	1967.50	177.50	406.0
12057	0012057	CB-15/Test	6/23/00		2640.80	197.30	490.20	41.80	3131.00	235.50	406.0
12058	0012058	CB-14&15/Field Blank	6/23/00		1098.30	130.10	0.00	25.70	1098.30	143.90	406.0
12059	0012059	CB-14&15/Field Blank	6/23/00		1461.70	143.10	0.00	25.70	1461.70	156.50	406.0
12060	0012060	CB-14&15/Field Blank	6/23/00		807.20	121.70	0.00	25.70	807.20	135.90	406.0
12061	0012061	CB-14&15/Field Blank	6/23/00		909.50	124.40	4.80	25.90	914.30	138.60	406.0
12062	0012062	CB-14&15/Field Blank	6/23/00		1224.10	134.30	171.80	110.00	1395.90	154.00	406.0
12063	0012063	Carbon Analysis Blank	Jun Test Period		651.10	118.00	0.00	25.70	651.10	132.50	406.0
12074	0012074	Carbon Analysis Blank	Extra		1058.70	128.80	0.00	25.70	1058.70	142.70	406.0
12075	0012075	Carbon Analysis Blank	Extra		1063.70	129.00	15.50	27.50	1079.30	143.40	406.0
12076	0012076	Carbon Analysis Blank	Extra		2177.20	174.40	140.20	91.00	2317.50	193.80	406.0

m2 Non-white carbon punch after carbon analysis, indicative of mineral particles in deposit.
QID Filter ID
OETF TOR analysis flag (see CHEMFLAG.doc)
OCTC Organic carbon concentration (μg/filter)
OCTU Organic carbon concentration uncertainty (μg/filter)
ECTC Elemental carbon concentration (μg/filter)
ECTU Elemental carbon concentration uncertainty (μg/filter)
TCTC Total carbon concentration (μg/filter)
TCTU Total carbon concentration uncertainty (μg/filter)
DEPAREA Filter deposit area (406 cm^2)

40

CHEMFLAG.DOC

Table
Chemical Analysis Data Validation Flags[a]

Validation Flag	Sub Flag	Description
b		Blank.
	b1	Field/dynamic blank.
	b2	Laboratory blank.
	b3	Distilled-deionized water blank.
	b4	Method blank.
	b5	Extract/solution blank.
	b6	Transport blank.
c		Analysis result reprocessed or recalculated.
	c1	XRF spectrum reprocessed using manually adjusted background.
d		Sample dropped.
f		Filter damaged or ripped.
	f1	Filter damaged, outside of analysis area.
	f2	Filter damaged, within analysis area.
	f3	Filter wrinkled.
	f4	Filter stuck to PetriSlide.
	f5	Teflon membrane separated from support ring.
	f6	Pinholes in filter.
g		Filter deposit damaged.
	g1	Deposit scratched or scraped, causing a thin line in the deposit.
	g2	Deposit smudged, causing a large area of deposit to be displaced.
	g3	Filter deposit side down in PetriSlide.
	g4	Part of deposit appears to have fallen off; particles on inside of PetriSlide.
	g5	Ungloved finger touched filter.
	g6	Gloved finger touched filter.
h		Filter holder assembly problem.
	h1	Deposit not centered.
	h2	Sampled on wrong side of filter.
	h4	Filter support grid upside down- deposit has widely spaced stripes or grid pattern.
	h5	Two filters in PetriSlide—analyzed separately.
i		Inhomogeneous sample deposit.
	i1	Evidence of impaction—deposit heavier in center of filter.
	i2	Random areas of darker or lighter deposit on filter.
	i3	Light colored deposit with dark specks.
	i4	Non-uniform deposit near edge—possible air leak.

41

Table
Chemical Analysis Data Validation Flags[a] (Continued)

Validation Flag	Sub Flag	Description
m		Analysis results affected by matrix effect.
	m1	Organic/elemental carbon split undetermined due to an apparent color change of non-carbon particles during analysis; all measured carbon reported as organic.
	m2	Non-white carbon punch after carbon analysis, indicative of mineral particles in deposit.
	m3	A non-typical, but valid, laser response was observed during TOR analysis. This phenomena may result in increased uncertainty of the organic/elemental carbon split. Total carbon measurements are likely unaffected.
n		Foreign substance on sample.
	n1	Insects on deposit, removed before analysis.
	n2	Insects on deposit, not all removed.
	n3	Metallic particles observed on deposit.
	n4	Many particles on deposit much larger than cut point of inlet.
	n5	Fibers or fuzz on filter.
	n6	Oily-looking droplets on filter.
	n7	Shiny substance on filter.
	n8	Particles on back of filter.
	n9	Discoloration on deposit.
q		Standard.
	q1	Quality control standard.
	q2	Externally prepared quality control standard.
	q3	Second type of externally prepared quality control standard.
	q4	Calibration standard.
r		Replicate analysis.
	r1	First replicate analysis on the same analyzer.
	r2	Second replicate analysis on the same analyzer.
	r3	Third replicate analysis on the same analyzer.
	r4	Sample re-analysis.
	r5	Replicate on different analyzer.
	r6	Sample re-extraction and re-analysis.
	r7	Sample re-analyzed with same result, original value used.
s		Suspect analysis result.
v		Invalid (void) analysis result.
	v1	Quality control standard check exceeded ±10% of specified concentration range.
	v2	Replicate analysis failed acceptable limit specified in SOP.
	v3	Potential contamination.
	v4	Concentration out of expected range.

42

Table
Chemical Analysis Data Validation Flags[a] (Continued)

Validation Flag	Sub Flag	Description
w		Wet Sample.
	w1	Deposit spotted from water drops.

[a] Analysis results are categorized as valid, suspect, or invalid. Unflagged samples, or samples with any flag except 's' or 'v' indicate valid results. The 's' flag indicates results of suspect validity. The 'v' flag indicates invalid analysis results. Chemical analysis data validation flags are all lower case.

Table B-2. Summary of Blank Filter Test Results

QID	Filter ID	Run/Description	Date	OETF	OCTC	OCTU	ECTC	ECTU	TCTC	TCTU	DEPA
12003	0012003	CB-1/Field Blank	4/7/00		1018.90	127.60	12.80	26.90	1031.80	141.90	406.0
12004	0012004	CB-2/Field Blank	4/7/00		859.50	123.00	0.00	25.70	859.50	137.20	406.0
12009	0012009	CB-3/Field Blank	4/8/00		694.70	119.00	0.00	25.70	694.70	133.40	406.0
12010	0012010	CB-3/Field Blank	4/8/00		782.20	121.00	0.00	25.70	782.20	135.30	406.0
12014	0012014	CB-4/Field Blank	4/9/00		860.80	123.10	37.50	34.70	898.30	138.20	406.0
12015	0012015	CB-4/Field Blank	4/9/00		1091.20	129.80	92.30	62.90	1183.40	146.60	406.0
12018	0012018	CB-5/Field Blank	4/10/00		802.60	121.50	19.60	28.50	822.20	136.30	406.0
12019	0012019	CB-5/Field Blank	4/10/00		1030.80	127.90	47.80	39.30	1078.60	143.30	406.0
12022	0012022	CB-6/Field Blank	4/11/00		723.40	119.60	0.00	25.70	723.40	134.00	406.0
12023	0012023	CB-6/Field Blank	4/11/00		1031.40	128.00	20.70	28.80	1052.10	142.50	406.0
12025	0012025	CB-6/Field Blank	4/11/00		1275.80	136.10	32.80	32.80	1308.60	150.90	406.0
		Average April Field Blank			**924.66**		**23.95**		**948.62**		
12030	0012030	CB-7&8/Field Blank	5/2/00		750.60	120.30	5.20	25.90	755.80	134.70	406.0
12031	0012031	CB-7&8/Field Blank	5/2/00		696.50	119.00	0.00	25.70	696.50	133.40	406.0
12034	0012034	CB-9/Field Blank	5/3/00		837.90	122.50	114.50	75.80	952.40	139.70	406.0
		Average May Field Blank			**761.67**		**39.90**		**801.57**		
12046	0012046	CB-10&11/Field Blank	6/21/00		1430.90	141.90	0.00	25.70	1430.90	155.30	406.0
12050	0012050	CB-12/Field Blank	6/22/00		1237.60	134.80	166.40	106.70	1403.90	154.30	406.0
12052	0012052	CB-12&13/Field Blank	6/22/00		1325.60	137.90	31.60	32.40	1357.20	152.60	406.0
12058	0012058	CB-14&15/Field Blank	6/23/00		1098.30	130.10	0.00	25.70	1098.30	143.90	406.0
12059	0012059	CB-14&15/Field Blank	6/23/00		1461.70	143.10	0.00	25.70	1461.70	156.50	406.0
12060	0012060	CB-14&15/Field Blank	6/23/00		807.20	121.70	0.00	25.70	807.20	135.90	406.0
12061	0012061	CB-14&15/Field Blank	6/23/00		909.50	124.40	4.80	25.90	914.30	138.60	406.0
12062	0012062	CB-14&15/Field Blank	6/23/00		1224.10	134.30	171.80	110.00	1395.90	154.00	406.0
		Average June Field Blank			**1181.54**		**28.97**		**1210.50**		
		Average Field Blank			**997.78**		**34.45**		**1032.22**		

Table B-2. Summary of Blank Filter Test Results (Continued)

QID	Filter ID	Run/Description	Date	OETF	OCTC	OCTU	ECTC	ECTU	TCTC	TCTU	DEPA
12012	0012012	Carbon Analysis Blank	Apr Test Period		927.80	124.90	1.40	25.70	929.20	139.00	406.0
12024	0012024	Carbon Analysis Blank	Apr Test Period		1057.90	128.80	13.00	27.00	1070.90	143.10	406.0
		Average April Lab Blank			**992.85**		**7.20**		**1000.05**		
12035	0012035	Carbon Analysis Blank	May Test Period		739.40	120.00	38.20	35.00	777.60	135.20	406.0
12037	0012037	Carbon Analysis Blank	May Test Period		963.70	125.90	204.10	129.60	1167.70	146.10	406.0
12040	0012040	Carbon Analysis Blank	May Test Period		2231.20	177.00	334.10	34.20	2565.30	206.00	406.0
		Average May Lab Blank			**1311.43**		**192.13**		**1503.53**		
12047	0012047	Carbon Analysis Blank	Jun Test Period		2275.70	179.10	332.60	34.10	2608.40	208.20	406.0
12051	0012051	Carbon Analysis Blank	Jun Test Period		1139.10	131.40	125.50	82.20	1264.60	149.40	406.0
12063	0012063	Carbon Analysis Blank	Jun Test Period		651.10	118.00	0.00	25.70	651.10	132.50	406.0
		Average Jun Lab Blank			**1355.30**		**152.70**		**1508.03**		
12074	0012074	Carbon Analysis Blank	Extra		1058.70	128.80	0.00	25.70	1058.70	142.70	406.0
12075	0012075	Carbon Analysis Blank	Extra		1063.70	129.00	15.50	27.50	1079.30	143.40	406.0
12076	0012076	Carbon Analysis Blank	Extra		2177.20	174.40	140.20	91.00	2317.50	193.80	406.0
		Average Lab Blank			**1298.68**		**109.51**		**1408.21**		
		AVERAGE BLANK			**1098.08**		**59.47**		**1157.55**		

Comments:

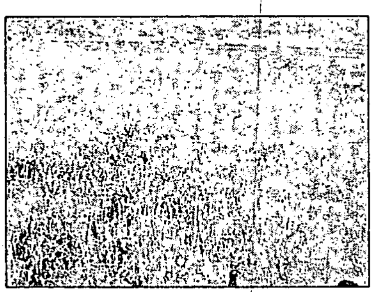
Lab blanks appear to have higher carbon concentrations than field blanks.
Lab blanks stored in freezer after weighing, while field blanks taken to field.
Organic carbon is 15 x higher than elemental carbon on blank filters, indicating absorption of VOCs
Grassy area tests (CB-4, 5, and 6) showed very little elemental carbon in emissions
First set of burned area tests (CB-1, 2, and 3) showed clear evidence of carbon emissions
Organic and elemental carbon emissions were approximately equal on tests CB-1, 2, and 3.

Appendix C

Time Series Photos of Prescribed Burn Area

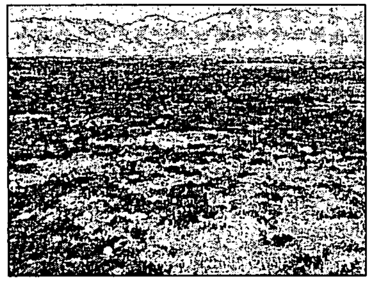
Time Series of 2000 Prescribed Burn Area at Rocky Flats Environmental Technology Site

Prescribed Burn Conducted on April 6, 2000

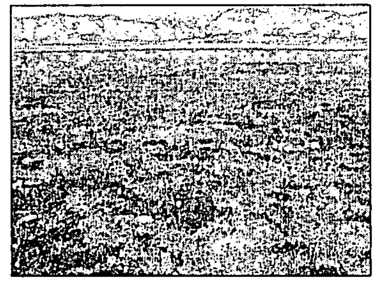


9/15/99

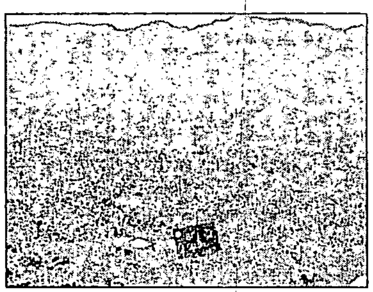
4/7/00



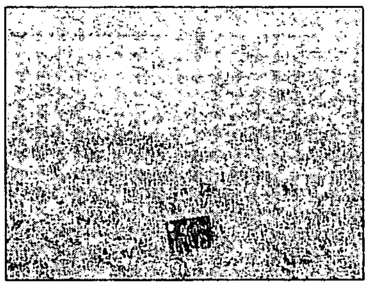
4/17/00



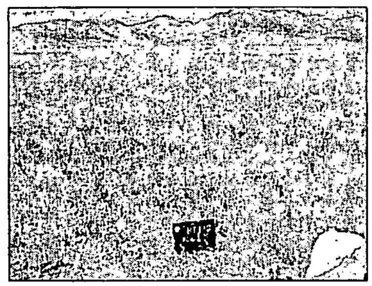
4/27/00



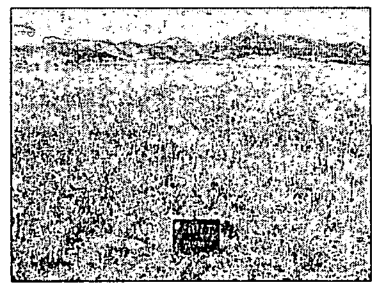
5/22/00



6/28/00



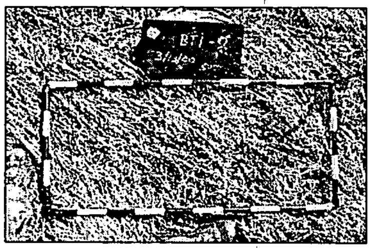
8/10/00



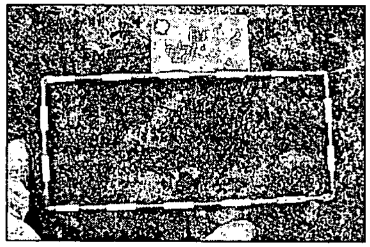
9/27/00

Time Series of Ground Surface in 2000 Prescribed Burn Area at Rocky Flats Environmental Technology Site

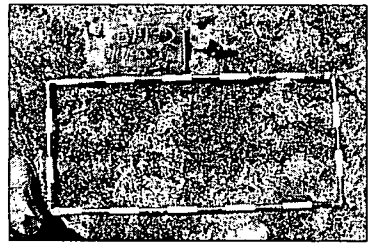
Prescribed Burn Conducted on April 6, 2000



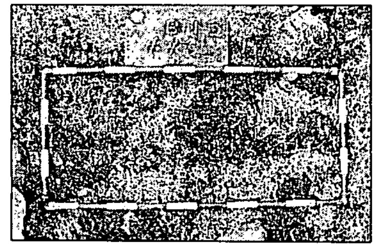
3/13/00



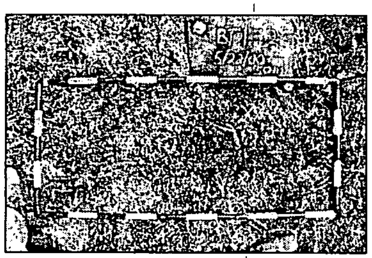
4/7/00



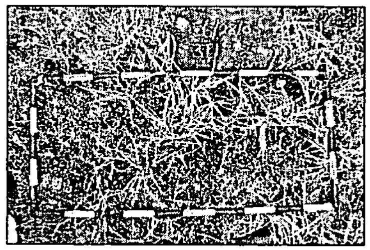
4/17/00



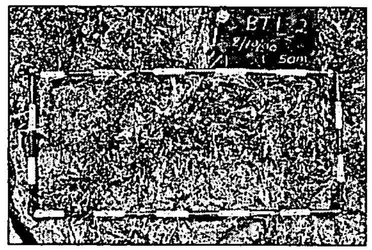
4/27/00



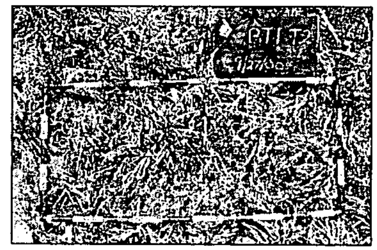
5/22/00



6/28/00



8/10/00



9/27/00

Appendix D

Example Calculation for Run CB-7

CB-7 EXAMPLE CALCULATION

Part I: Calculation of tunnel effluent concentrations

- Duration of testing:
  CB-7A = 30 min
  CB-7B = 27 min
  CB-7C = 37 min
  CB-7 = 94 min

- Blank-corrected backup filter net weight:
  Tare weight = 3293.05 mg
  Final weight = 3302.20 mg
  Blank correction = 0.00 mg
  Filter net weight = 9.15 mg
  *Net weight constitutes PM-10 mass collected by effluent sampler

- Cyclone flow rate = 40 cfm = 68 m^3/h = 1.13 m^3/min

Average effluent PM-10 concentration:

$$\frac{9.15 \text{ mg}}{1.13 \text{ m}^3/\text{min} \times 94 \text{ min}} = 0.085 \text{ mg/m}^3$$

- Blank-corrected background filter net weight:
  Tare weight = 3300.20 mg
  Final weight = 3319.80 mg
  Blank correction = 0.00 mg
  Filter net weight = 19.60 mg
  *Half of net weight assumed to be PM-10 mass collected from ambient air
  PM-10 mass collected = 9.80 mg

- Duration of background sampling = 217 min
- Cyclone flow rate = 40 cfm = 68 m^3/h = 1.13 m^3/min

Background PM-10 concentration:

$$\frac{9.80 \text{ mg}}{1.13 \text{ m}^3/\text{min} \times 217 \text{ min}} = 0.040 \text{ mg/m}^3$$

Net PM-10 Concentration (attributable to emissions from test area):

$0.085 \text{ mg/m}^3 - 0.040 \text{ mg/m}^3 = 0.045 \text{ mg/m}^3$

- Cyclone catch:
  Bag tare weight = 3.6875 g
  Bag final weight = 3.7259 g
  Bag net weight = 0.0384 g = 38.4 mg
  *Sample collected in bag represents suspended particles greater than 10 µm aerodynamic diameter

Average effluent TP concentration:

$$\frac{9.15 \text{ mg} + 38.4 \text{ mg}}{1.13 \text{ m}^3/\text{min} \times 94 \text{ min}} = 0.448 \text{ mg/m}^3$$

Part II: Calculation of erosion potentials

- Average maximum Δp at tunnel centerline (CL) during test runs:

CB-7A	=	0.49 in. H_2O
CB-7B	=	0.49 in. H_2O
CB-7C	=	0.64 in. H_2O
CB-7	=	0.54 in. H_2O

- Factor conversion of Δp to wind speed (mph):
  Average barometric pressure = 24.3 in. Hg
  Ambient temperature = 65°F

$$K' = 10.83 \times \left(\frac{(65°F + 459.3)}{24.3 \text{ in. Hg}}\right)^{1/2} = 50.305$$

Maximum wind speed (mph) at tunnel CL:

$$50.305 \times (0.54 \text{ in. } H_2O)^{1/2} = 37.0 \text{ mph}$$

- Average surface roughness height for test period:

CB-7A	=	0.90 cm	CB-8A	=	1.20 cm	CB-9A	=	1.73 cm
CB-7B	=	1.22 cm	CB-8B	=	1.20 cm	CB-9B	=	1.42 cm
CB-7C	=	1.19 cm	CB-8C	=	1.52 cm	CB-9C	=	1.57 cm
CB-7	=	1.10 cm	CB-8	=	1.31 cm	CB-9	=	1.57 cm

  Average roughness height = 1.33 cm

- ~~Tunnel CL height = 15.2 cm~~

Equivalent maximum wind speed (mph) at 10-m height:

$$\frac{37.0 \text{ mph} \times \ln \dfrac{1000 \text{ cm}}{1.33 \text{ cm}}}{\ln \dfrac{15.2 \text{ cm}}{1.33 \text{ cm}}} = 100.6 \text{ mph}$$

Corresponding friction velocity:

$$\frac{37.0 \text{ mph} \times 0.4}{\ln \dfrac{15.2 \text{ cm}}{1.33 \text{ cm}}} = 6.08 \text{ mph} = 271.8 \text{ cm/s}$$

- Net PM-10 mass collected:

$$9.15 \text{ mg} - (9.80 \text{ mg} \times \frac{94 \text{ min}}{217 \text{ min}}) = 4.90 \text{ mg} = 0.00490 \text{ g}$$

*Background mass time-weighted to emission sampler run time

- Ratio of sampling extension area to inlet nozzle area:
  Sampling extension i.d. = 7.874 in   Sampling extension area =48.69 in^2
  Intake nozzle i.d.= 0.88 in   Intake nozzle area = 0.608 in^2
  Ratio = 80.08

- Area of ground surface sampled = 0.918 m^2

PM-10 erosion potential/loss:

$$\frac{0.00490 \text{ g} \times (80.08 \times 85\%)}{3 \times 0.918 \text{ m}^2} = 0.12 \text{ g/m}^2$$

*Three tests areas sampled during CB-7
*85% of the centerline wind speed is the average wind speed over the area of the sampling extension

TP erosion potential/loss:

$$\frac{(0.00490 \text{ g} + 0.0384 \text{ g}) \times (80.08 \times 85\%)}{3 \times 0.918 \text{ m}^2} = 1.07 \text{ g/m}^2$$

*Three tests areas sampled during CB-7
*85% of the centerline wind speed is the average wind speed over the area of the sampling extension

Part III: Calculation of carbon contribution to PM-10 mass

- Emission sampler filter:
  PM-10 mass collected = 9.15 mg
  Organic carbon = 3011.00 μg/filter
  Elemental carbon = 829.00 μg/filter
  Sampling duration = 94 min

- Background filter:
  PM-10 mass collected = 9.80 mg
  Organic carbon = 4505.30 μg/filter
  Elemental carbon = 468.30 μg/filter
  Sampling duration = 217 min

- Average blank filter:
  Organic carbon = 1098.08 μg/filter
  Elemental carbon = 59.47 μg/filter

Emission sampler blank-corrected organic carbon:

3011.00 μg/filter – 1098.08 μg/filter = 1912.92 μg/filter
*Organic carbon contributed to PM-10 mass on filter

Emission sampler blank-corrected elemental carbon:

829.00 μg/filter – 59.47 μg/filter = 769.53 μg/filter
*Elemental carbon contributed to PM-10 mass on filter

Adjusted background sampler net mass:

$$9.80\ \text{mg} \times \frac{94\ \text{min}}{217\ \text{min}} = 4.25\ \text{mg}$$

*Background mass time-weighted to emission sampler run time

Background sampler blank corrected organic carbon:

4505.30 μg/filter – 1098.08 μg/filter = 3407.22 μg/filter

Adjusted background sampler blank corrected organic carbon:

$$3407.22\ \mu\text{g/filter} \times 50\% \times \frac{94\ \text{min}}{217\ \text{min}} = 737.97\ \mu\text{g/filter}$$

*Half of net carbon collected on filter assumed to be PM-10
*Background mass time-weighted to emission sampler run time

53

Background sampler blank corrected elemental carbon:

468.30 μg/filter – 59.47 μg/filter = 408.83 μg/filter

Adjusted background sampler blank corrected elemental carbon:

$$408.83\ \mu g/\text{filter} \times 50\% \times \frac{94\ \text{min}}{217\ \text{min}} = 88.55\ \mu g/\text{filter}$$

*Half of net carbon collected on filter assumed to be PM-10
*Background mass time-weighted to emission sampler run time

Net PM-10 mass:

9.15 mg – 4.25 mg = 4.9 mg

Net organic carbon:

1912.92 μg/filter - 737.97 μg/filter = 1174.95 μg/filter

1.17 mg organic carbon in PM-10 mass

Net elemental carbon:

769.53 μg/filter - 88.55 μg/filter = 680.98 μg/filter

0.68 mg elemental carbon in PM-10 mass

Net total carbon:

1.17 mg organic + 0.68 mg elemental = 1.85 mg